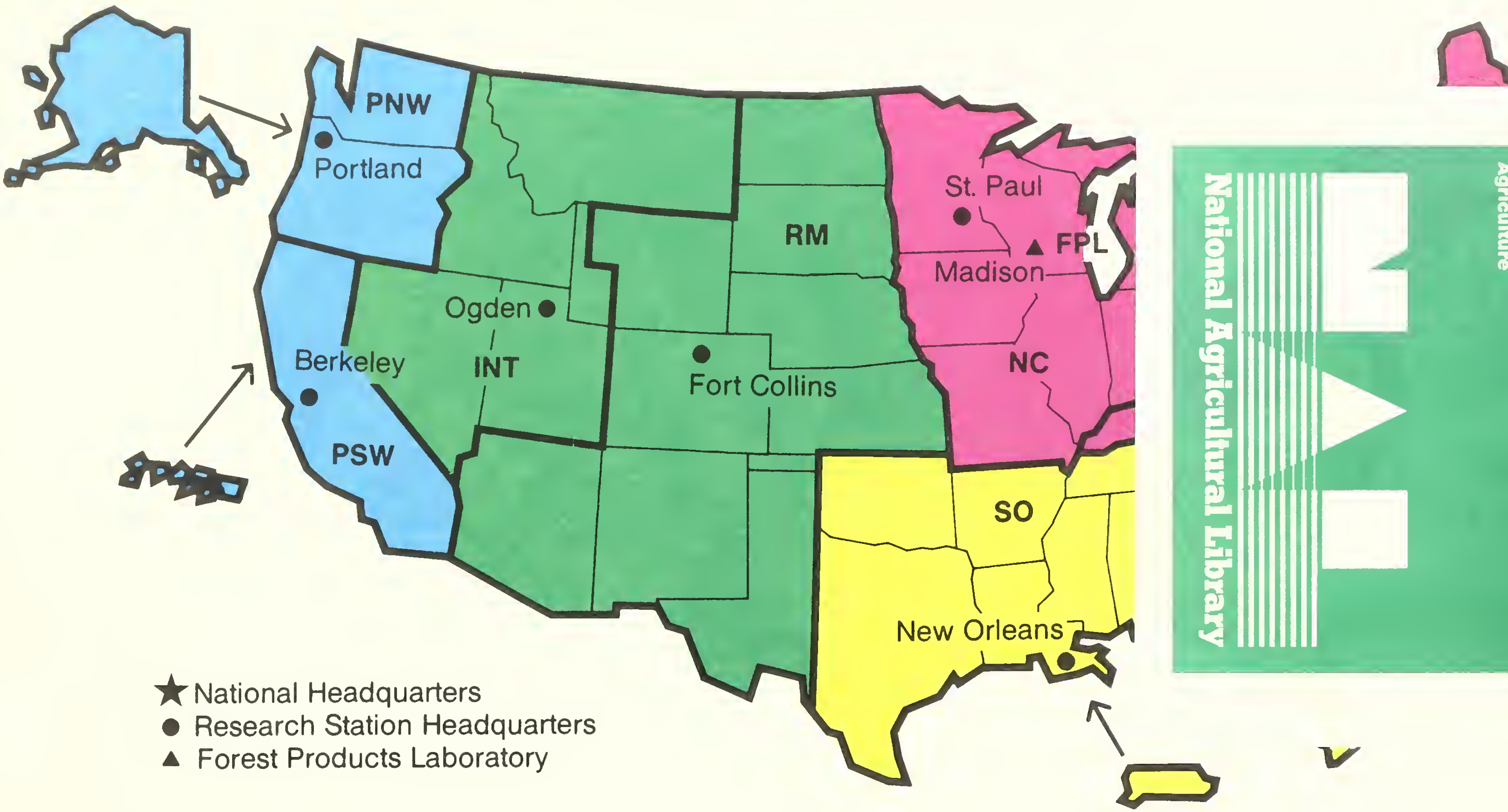
GLOBAL CHANGE RESEARCH PROGRAM PLAN

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

May 1990

Forest Service Regions and Experiment Stations



Northern Region:
Northeastern Forest Experiment Station (NE)
North Central Forest Experiment Station (NC)

Southern Region:
Southeastern Forest Experiment Station (SE)
Southern Forest Experiment Station (SO)

Interior West Region:
Intermountain Forest & Range Experiment Station (INT)
Rocky Mountain Forest & Range Experiment Station (RM)

Pacific Coastal Region:
Pacific Northwest Forest & Range Experiment Station (PNW)
Pacific Southwest Forest & Range Experiment Station (PSW)

GLOBAL CHANGE RESEARCH PROGRAM PLAN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

Workshop, Peer Review, and
Editorial Production of Report Conducted By:

Science and Policy Associates, Inc.
The West Tower, Suite 400
1333 H Street, NW
Washington, DC 20005

May 1990

Cover photo courtesy of NASA: Applications Technological Satellite (ATS III) photo of North and South America. The picture was taken January 21, 1968, from a 22,300 mile altitude at 95 degrees West longitude above the equator. Baja, California, and the U.S. West Coast are clearly visible along with Mexico, Central America, Gulf Coast, Florida, U.S. East coast, and portions of the Great Lakes are shrouded by clouds.

TABLE OF CONTENTS

PREFACE

Global Change is an issue that has burst to the forefront of world interest. Man's activities have produced a measured, significant change in the chemical make-up of the atmosphere since the beginning of the industrial revolution. Measured changes in certain trace gases are projected to continue at an accelerated rate into the foreseeable future. These measured and projected changes of the chemical climate have been translated into predicted changes of the physical climate, the most notable being an increase of global atmospheric temperature. The accuracy and reliability of these predicted changes in the earth's climate are the subject of considerable debate among scientists and other concerned individuals, groups, and governments.

Forests, along with crop and pasture lands, provide the fundamental underpinning of the world economy because they supply most of the renewable resources needed to sustain global productivity. Forests are also the prime terrestrial base for sustaining global environmental productivity, health, and diversity. Forest ecosystems exist, from establishment through composition and stability, as a function of climate. In the more distant past, the earth's climate has changed and the forests became very different under those dissimilar prevailing climates. The evolution of North American forests during the past 10,000 years since the end of the last ice age provides dramatic evidence of the impact of climate change on forest placement, composition, and structure.

Global Change should be viewed as a <u>resource</u> issue. Forest and other renewable resource managers will be faced with major challenges if predicted climate changes prove to be accurate. Forest Service Research is the largest single source in the world for natural resource scientific expertise. Forest Service Research maintains the largest long-term land base of experimental sites and accompanying data records. In terms of responsibility and ability, Forest Service Research must address Global Change issues as they pertain to forests and related ecosystems.

We have focused our energies over four years on developing the Forest Service Global Change Research Program. During that time we have participated in the development of the Committee on Earth and Environmental Sciences (CEES) U.S. Global Change Research Program and the Intergovernmental Panel on Climate Change (IPCC). These partnerships have resulted in the full integration of the Forest Service program into the overall U.S. Global Change Program. The peer reviewed report that follows is the latest in a building series of planning efforts. It is founded on input from a November 1989 Workshop held in Baltimore, Maryland. Forest Service scientists, cooperating scientists from other agencies, and forest managers produced that Workshop's results. Appendix A lists workshop participants and Appendix B lists workshop breakout group participants. Those results built on a previously published report from a Spring 1988 Forest Service Workshop on Global Change, on the U.S. Global Change Research Program Plan, and on other sources including IPCC draft documents and the draft USDA Strategic Plan for Global Change.

The Forest Service Global Change Research Program has been founded on an ecosystem approach. We continue to emphasize that foundation. We build upon it to address issues such as enhancing carbon sequestration in long lasting forest products; assessing the impact of Global

Change on forests and related ecosystems; developing and evaluating adaptive and mitigative response strategies; focusing modeling to help understand forest ecosystem processes while delivering needed assessments and policy guidance; and launching a National Forest Health Monitoring Program to monitor for indications of Global Change within an overall effort to observe and report on the condition of U.S. forests. Our Program is managed through four regional cooperatives, a cooperative for forest product issues, and a monitoring cooperative, all under a National Program Coordinator. This report presents a national view with a national scale of resolution. Each of the regional cooperatives and the monitoring program are developing plans under this national umbrella. The regional plans supply greater specificity and emphasize the science needed to address those problems of greatest concern to the forest ecosystems in a given region. These regional plans will be available in the near future, as will detailed plans for Monitoring and Modeling. An updated version of this report will be published in 1991. We encourage readers to contact the National Program Coordinator and/or Regional Program Managers for more information. Their addresses are given in Appendix C.

EXECUTIVE SUMMARY

This report documents the main components of the Forest Service Global Change Research Program (FSGCRP). Forests and related ecosystems are vital to global economic and environmental sustainability. Observed and predicted changes in the global environment, if accurate, portend major impacts on forest productivity, health, and diversity. Global change is essentially a resource issue, since terrestrially based renewable resources required for sustainable development would be a focus of global change impacts and response strategies. Regional scale impacts would predominate.

The FSGCRP has been developed from an ecosystem perspective. Forest Service research needs to provide a sound scientific basis for making regional, national and international management and policy decisions regarding forest ecosystems in the context of global change issues.

The Forest Service needs to provide the scientific basis to address three broad questions concerning global change and forest ecosystems:

1. What processes in forested ecosystems are sensitive to physical and chemical changes in the atmosphere? ***Or in policy terms: is there a problem?***

2. How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes? ***Or in policy terms: how serious is the problem?***

3. What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity? ***Or in policy terms: what can be done about the problem?***

The Forest Service has worked with other Federal agencies under the Committee on Earth and Environmental Sciences (CEES)[1] structure to develop the U.S. Global Change Research Program (USGCRP). The FSGCRP is entirely consistent with the CEES program. The Forest Service has also been active in Intergovernmental Panel on Climate Change (IPCC) planning and the FSGCRP incorporates knowledge gained in those activities.

This report presents an overview of the global change issue from a natural resource perspective; shows the specific linkages between the FSGCRP and the USGCRP; provides broad descriptions of the science being initiated by the Forest Service; briefly explains the Forest Service management structure in place; and describes the activities to be undertaken by four newly established regional cooperatives. In addition, monitoring, modeling, assessment, response strategy, and policy formulation and evaluation activities to be undertaken, are presented.

More detailed programmatic descriptions are being developed for the four regional ecosystem cooperatives, as well as for monitoring, modeling, assessment, response strategy, and policy activities. These descriptions will be published shortly. This report will be updated in 1991.

1. Formerly the Committee on Earth Sciences (CES)

GLOBAL CHANGE -- OVERVIEW

INTRODUCTION

Forests and related ecosystems, both managed and unmanaged, constitute one of the three major terrestrial bases for global environmental and economic sustainability. Along with cropland, pasturelands, and the sea, forests provide the renewable resources that sustain life on earth. Forest lands cover one third of the land area of the earth. The physical and chemical state of the earth's atmosphere, collectively represented by climate, largely determine the presence and composition of forests. Forests, in turn, contribute to the determination of the earth's climate.

The earth's environment is a dynamic system that varies temporally and spatially, in response to both natural phenomena and human activities. Recent scientific and public interest has focused on the accumulation of greenhouse gases associated with human activities and the predicted changes of the global climate that are likely to result. Prominent among these changes are global warming, dislocation of precipitation regimes, and altered storm intensities. Other concerns have focused on stratospheric ozone depletion, acid deposition, tropical rain forest elimination, and increased global energy demands. Secondary effects such as changes in drought or flood frequency and severity, insect and disease outbreaks, and fire frequency and severity will impact our forests, range ecosystems, and watersheds. These changes in earth's atmosphere and their interaction with the biosphere, hydrosphere, and human community are collectively known as global change.

Forests and related ecosystems are major components of the terrestrial biosphere portion of earth's environment. Forest productivity, health, and diversity must be sustained to reduce contributions to environment change. If accurate, predicted climate changes would profoundly affect forest ecosystems, and forest ecosystem changes would profoundly affect the global environment. Global change cannot be predicted without knowledge of the role of forest ecosystems; at the same time, knowledge of global change is necessary to predict the future of forest ecosystems. Reliable assessments of global change impacts must incorporate knowledge of forest ecosystems. Reliable assessments of forest ecosystem productivity, health, and diversity also must incorporate global change information. Response strategies for global change mitigation and adaptation, and global change policy options need to include forest ecosystems as part of their central focus.

Forest Service research is founded on the need to describe and understand natural resource systems, to assess the condition of those systems, and to predict their future status. Global change is, at its core, a resource issue that portends fundamental changes in the resources that are the basis of the Forest Service mission. Global change challenges the Forest Service and other resource managers with a scope and complexity never before faced. The emergence of the global change issue has placed traditional Forest Service Research missions, scientific abilities, and experimental capabilities in the forefront of needs recognized in national and international plans for global change research, monitoring, modeling, assessment, response strategies, and policy formulations.

Government activities under way at the international, national, and departmental levels have established the framework for the Forest Service Global Change Research Program. Three activities are of particular importance: the Intergovernmental Panel on Climate Change (IPCC) at the international level; the United States Global Change Research Program Plan of the Committee on Earth and Environmental Sciences (CEES) at the national level; and the United States Department of Agriculture (USDA) Global Change Strategic Plan at the departmental level. IPCC is studying the problem in terms of (1) Scientific Assessment, (2) Impact Assessment, and (3) Response Strategies. All three areas emphasize forest ecosystems. The CEES Plan represents the Global Change Research Program of the U.S. Government. The Forest Service Global Change Research Program is reflected in the CEES Plan. The USDA Plan addresses both the IPCC and CEES activities and includes additional emphasis on policy issues. The science section parallels the CEES Plan. Assessment, Response Strategy, and Policy Strategy sections are added in the USDA Plan with an emphasis on resource management issues and an ecosystem approach.

Forest Service research planning for global change has been, and continues to be, founded on an ecosystem approach. The principle purpose of Forest Service research is to understand the role of the atmospheric environment in forest ecosystems and to predict how this role will evolve under global change scenarios. The Forest Service approach is to not only study environmental change from an ecosystem perspective, but to assure national cohesion and integrated scope, particularly for cross-cutting areas such as monitoring and modeling. The goal is to be able to predict the impacts of global change on sustainable forest ecosystem resources and to provide forest resource managers with viable response strategies and policy options for sustaining forest productivity, health, and diversity.

BACKGROUND

Several trends involving observational technology, systems views of the earth's biosphere, ecological perspectives in forestry, multiple stress effects in natural ecosystems, and observed changes in the chemical composition of the earth's atmosphere and their predicted impact on global climate, have converged in scientific, public, and policy concern over global change. The ability to observe the earth from space has lead to greater emphasis on understanding the earth as a system, and the terrestrial biosphere as a very major component of that system. The ability to more precisely monitor atmospheric chemistry has revealed a major and continuing increase in radiatively active gases (carbon dioxide, methane, etc.). The role of these "greenhouse" gases in maintaining the earth's global temperature has long been known. Incorporation of the observed increasing concentration trends in computer simulations, known as general circulation models (GCMs), resulted in predictions of increases in global mean temperatures and associated, but less accurately defined, disruptions of observed precipitation patterns. Forested lands will be affected by, and forest practices are contributing to, predicted changes. Forests and related ecosystems are increasingly recognized as vital components of a productive, healthy, and diverse earth system. From a forest ecosystem viewpoint, the Forest Service has recognized that fundamental processes cannot be understood if they are studied as a closed system or as subject only to independent, isolated, singular stresses. Rather, to understand forest ecosystems and to predict their future state they must be considered as parts of larger systems and as acted upon by multiple stresses.

OBJECTIVES

Forest Service research needs to provide a sound scientific basis for making regional, national and international management and policy decisions regarding forest ecosystems in the context of global change issues.

Forest Service needs to provide the scientific basis to address three broad questions concerning global change and forest ecosystems:

1. What processes in forested ecosystems are sensitive to physical and chemical changes in the atmosphere?
   Or in policy terms: is there a problem?

2. How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes?
   Or in policy terms: how serious is the problem?

3. What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity?
   Or in policy terms: what can be done about the problem?

To answer these questions, the Forest Service needs to assure that responses of forest ecosystems to global change are adequately monitored, understood, and modeled. Furthermore, these activities need to be integrated into the overall Forest Service research goals. The research program must reflect benefits to the forest manager as well as contribute to the development of scientific understanding, impact assessments, response strategies, and policy options. This Forest Service Global Change Research Program ten year plan is intended to be consistent with the development of IPCC, CEES, and USDA plans.

THE UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM

A United States Global Change Research Program Plan (USGCRP) has been developed under the direction of the Office of Science and Technology Policy in the Executive Office of the President, through the Federal Coordinating Council on Science, Engineering and Technology (FCCSET) and its Committee on Earth and Environmental Sciences (CEES). Figure 1 shows the relationship of various federal entities involved with the USGCRP.

The goal of the USGCRP is:

To gain an adequate predictive understanding of the interactive physical, geological, chemical, biological and social processes that regulate the total earth system and, hence establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts.

Meeting the goal of the USGCRP will require addressing the following major questions:

1. What global changes have occurred in the past and are occurring now?

2. What physical, geological, chemical, social, and biological processes are involved in regulating global change and its environmental impacts?

3. How well can global change and its impacts be predicted?

The strategy for implementing the USGCRP requires the identification of scientific objectives, the integration of traditional scientific disciplines, and the establishment of new institutional structures.

The scientific objectives of the USGCRP are to monitor, understand, and ultimately predict global change. The USGCRP is broad in scope, encompassing the full range of earth system changes, including physical, chemical, geological, social, and biological changes. The USGCRP addresses both natural phenomena as well as the effects of human activity.

Particular CEES-supported research activities are grouped into seven multi-disciplinary scientific elements in the following priority order:

CEES Scientific Elements

1. Climate and Hydrologic Systems
2. Biogeochemical Dynamics
3. Ecological Systems and Their Dynamics
4. Earth System History
5. Human Interactions
6. Solid Earth Processes
7. Solar Influences

The Forest Service currently addresses the first five elements, but does not address solid-earth processes or solar influences. Figure 2 outlines the CEES elements. Descriptions of these CEES interdisciplinary science elements are as follows:

Figure 1

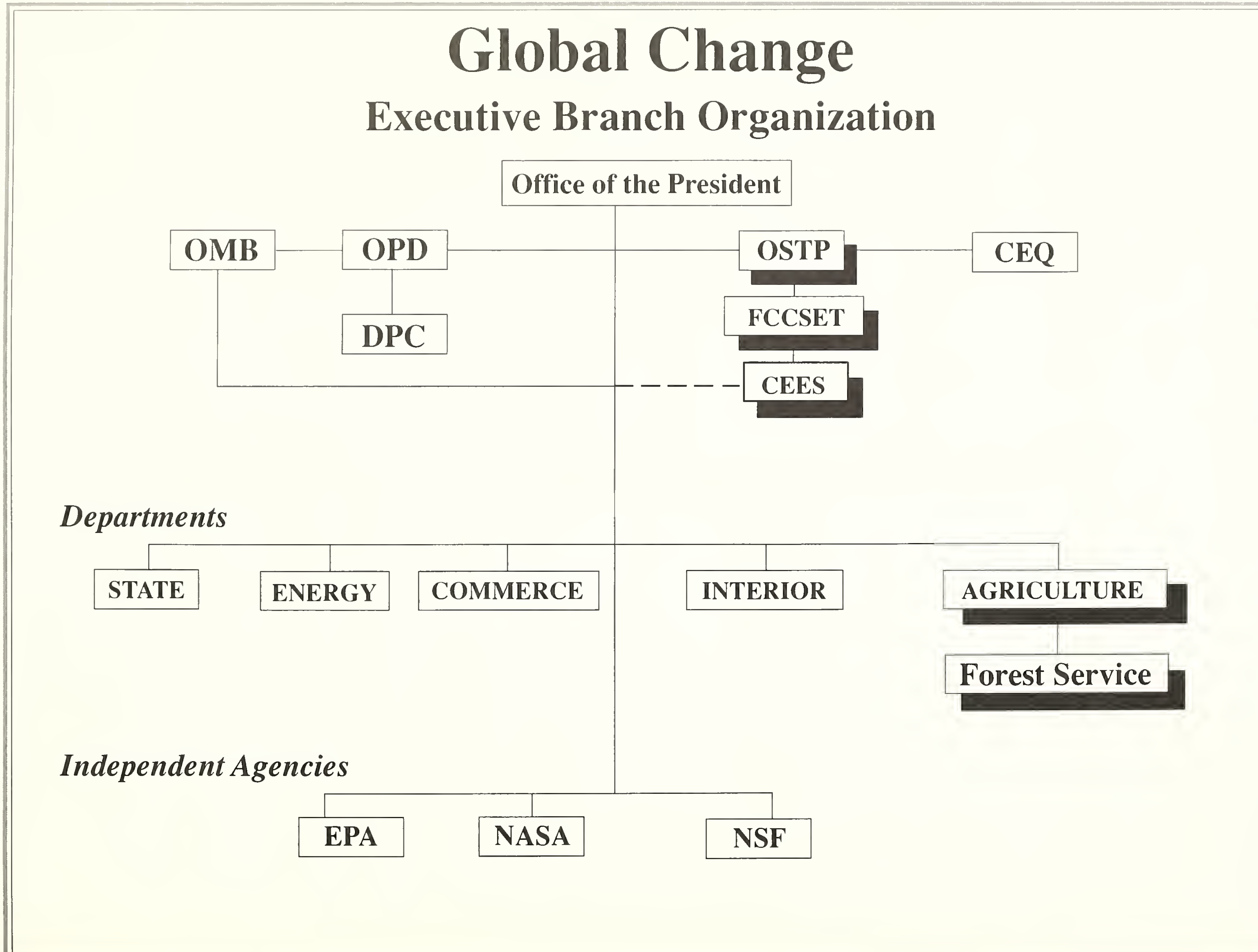
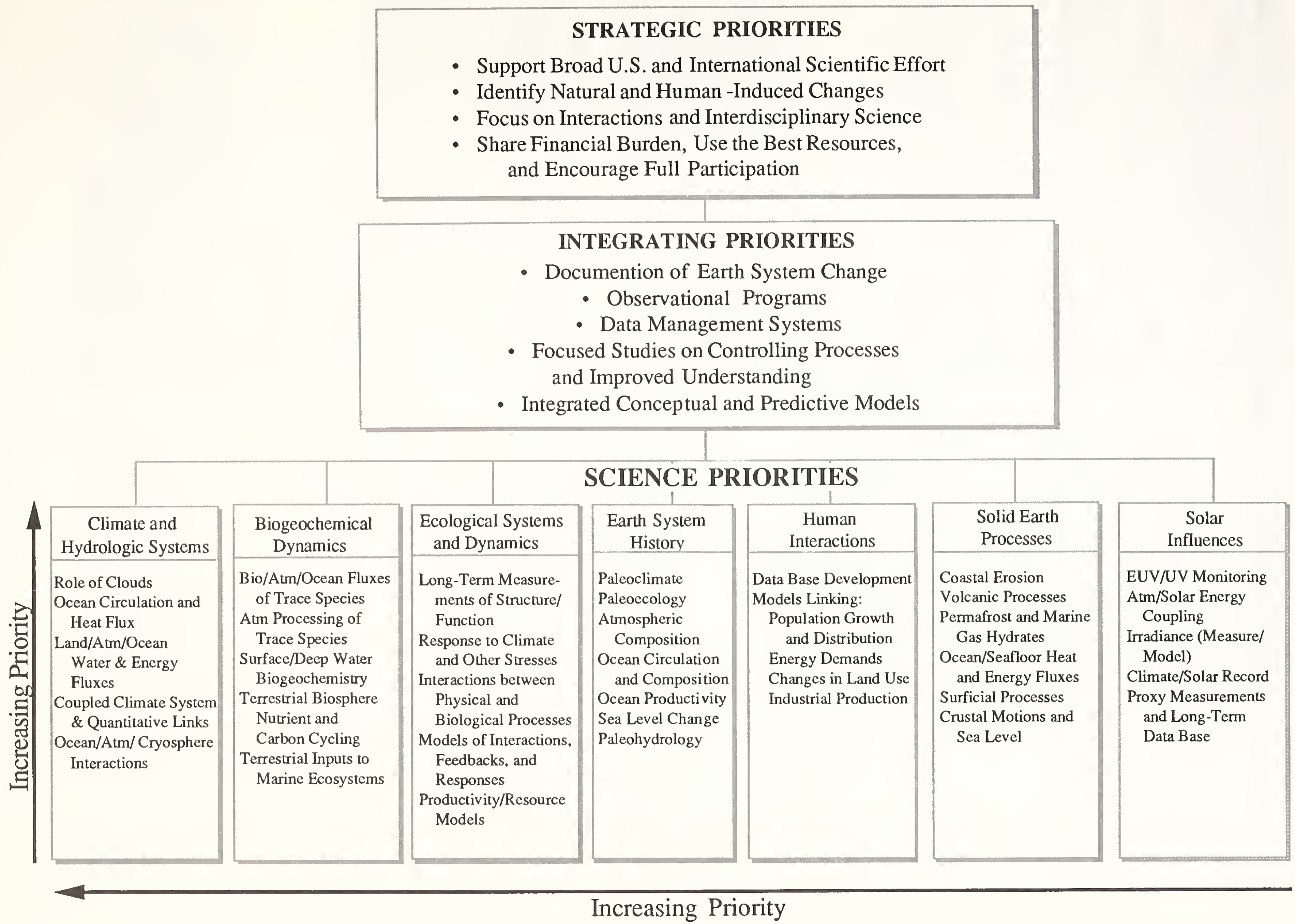

Global Change
Executive Branch Organization
Office of the President
OMB
OPD
DPC
OSTP
FCCSET
CEES
CEQ
Departments
STATE
ENERGY
COMMERCE
INTERIOR
AGRICULTURE
Forest Service
Independent Agencies
EPA
NASA
NSF

Figure 2

U.S. Global Change Research Program Priority Framework



Climate and Hydrologic Systems

Definition. Includes the study of the physical and biological processes that govern physical climate and the hydrologic cycle, including interactions between the atmosphere, hydrosphere (i.e., oceans, surface and ground water, clouds, etc.), cryosphere (i.e., ice and snow cover), land surface, and biosphere.

Activities. Includes studies to improve the understanding of (i) the role of clouds in the radiation budget of the atmosphere; (ii) the fluxes of energy and water between the atmosphere, biosphere, and land and ocean surfaces; and (iii) the quantitative links -- including feedbacks -- in the climate system between atmosphere, ocean, cryosphere, land surface, and biosphere.

Biogeochemical Dynamics

Definition. Includes the study of the sources, sinks, fluxes, trends, and interactions involving the biogeochemical constituents within the earth system, including those resulting from human activities; with a focus on carbon, nitrogen, sulfur, oxygen, phosphorus, and the halogens.

Activities. Includes studies to improve the understanding of (i) the fluxes of radiatively and chemically active species between the atmosphere, biosphere, and land and ocean surfaces; (ii) the cycling and transformation within the terrestrial biosphere of nutrients and carbon; and (iii) the terrestrial flux of nutrients and carbon to coastal waters and marine ecosystems.

Ecological Systems and Dynamics

Definition. Includes the study of the responses of ecological systems, both marine and terrestrial, to changes in global and regional environmental conditions and the study of the influence of biological communities on the atmospheric, terrestrial, marine, and climatic systems.

Activities. Includes studies on (i) the structure and function of biological systems on various time scales; (ii) the response of species, ecological communities, natural and managed ecosystems to carbon dioxide, climate and physical/chemical stresses; (iii) the interactions between physical and biological processes on varying time and space scales; (iv) modeling ecological and physical climate interactions; and (v) modeling of biological productivity of natural and managed ecosystems.

Earth System History

Definition. Includes the study and interpretation of the natural records of past environmental change that is contained in terrestrial and marine sediments, soils, glaciers and permafrost, tree rings, rocks, geomorphic features, and other direct or proxy documentation of past global conditions.

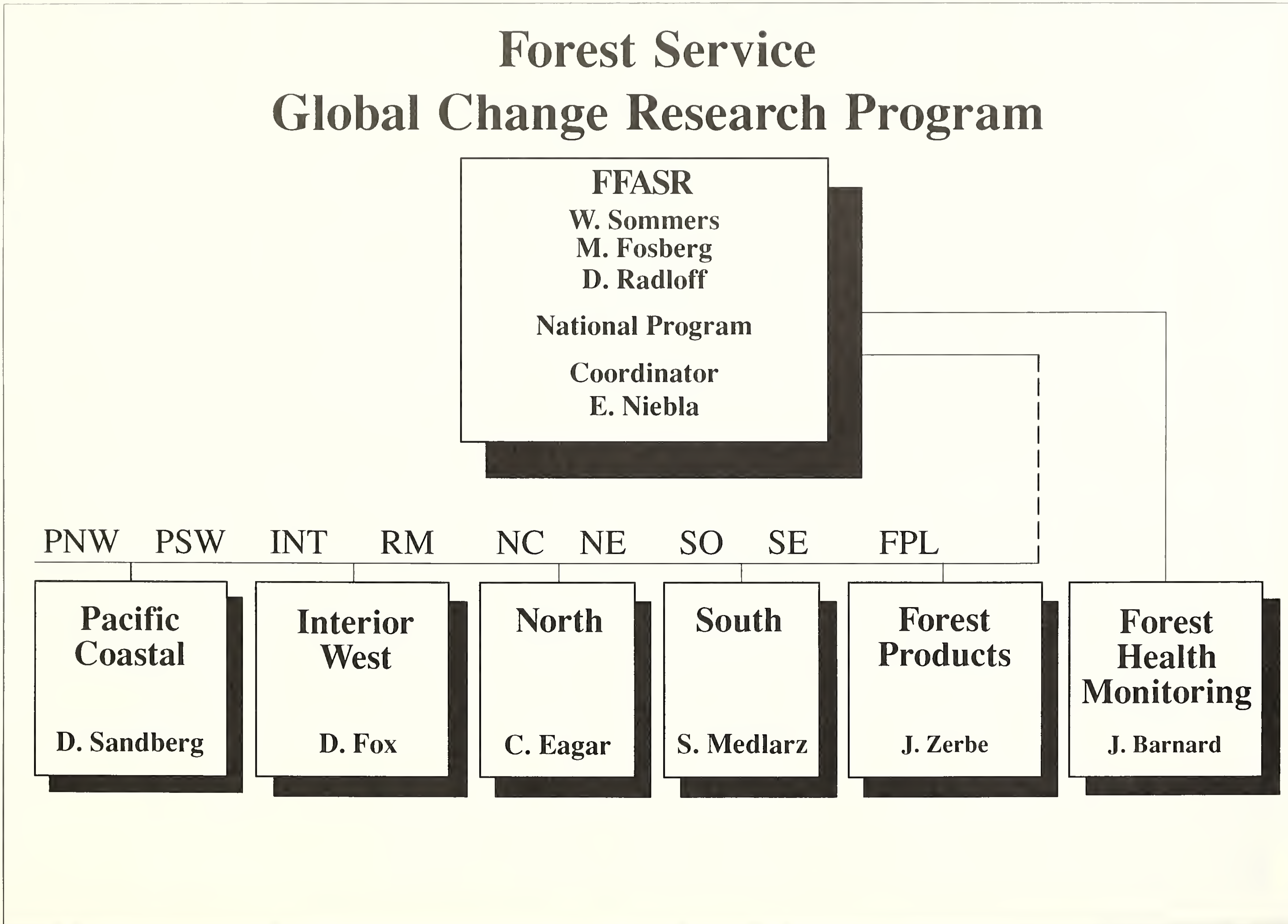
Activities. Includes studies to reconstruct the earth's climates and environments on both regional and global scales from evidence preserved in the geologic record; including past (i) natural variability of climate on all time scales; (ii) responses of ecosystems to climate change; (iii) changes in the composition of earth's atmosphere; (iv) changes in ocean circulation and composition; and (v) changes in surface and ground water in response to climate change.

Human Interactions

Definition. Includes the study of (i) the social factors that influence the global environment, such as population growth, industrialization, agricultural practices, and other land usages; and (ii) the human activities that are impacted by regional aspects of global change.

Activities. Includes the study and development of (i) long-term, comparable, cross-national data bases that encompass human activities, such as land use practices, energy transformations, legal and regulatory requirements, and economic behavior; and (ii) models linking population growth and distribution, energy demands, changes in land use, and industrial production.

Figure 3


Forest Service
Global Change Research Program
FFASR
W. Sommers
M. Fosberg
D. Radloff
National Program
Coordinator
E. Niebla
PNW
PSW
INT
RM
NC
NE
SO
SE
FPL
Pacific Coastal
D. Sandberg
Interior West
D. Fox
North
C. Eagar
South
S. Medlarz
Forest Products
J. Zerbe
Forest Health Monitoring
J. Barnard

FOREST SERVICE GLOBAL CHANGE PROGRAM NATIONAL PERSPECTIVES

FOREST SERVICE MISSION AND ROLE

The Forest Service Global Change Research Program (FSGCRP) is built on the base of Forest Service expertise gained through 90 years of ecosystem research and recent atmospheric deposition research. It takes a complete ecosystem view of the interactions between forests and the atmospheric components that affect forest productivity, health, and diversity. The Forest Service will support long-term research, fundamental science, monitoring, and develop predictive capability which will address effects of multiple pollutants and atmospheric change on forest and range ecosystems.

The ongoing commitment of the Forest Service to long-term research is exemplified by the coverage of forest ecosystems from Alaska to Puerto Rico and from Maine to the Pacific Islands in plots and small watersheds established in Experimental Forests, Rangelands, Watersheds and in Research Natural Areas. The Forest Service has outstanding capabilities to undertake long-term research and monitoring of global change within ecosystems. A significant long-term commitment in documenting the subtle changes anticipated with global change along and across ecotones will be required to meet the challenges posed.

The Forest Service has supported research on the impacts of climate and weather on forests for many decades and research on forest responses to atmospheric pollutants since the early 1970s. The Forest Service has been a national leader in acidic deposition research through the Forest Response Program, in cooperation with Environmental Protection Agency and National Council of the Paper Industry for Air and Stream Improvement (NCASI).

All eight regional Forest Service Research Stations and the Forest Products Laboratory have work units actively engaged in research related to global change. These efforts fall within Forest Service research categories: Timber Management; Forest Environment; Forest Fire and Atmospheric Sciences; Forest Insect and Disease; Forest Inventory, Economics, and Recreation; and Forest Products and Harvesting Research.

The Forest Service has developed an extensive network of forest monitoring sites and measurement expertise as part of its traditional programs aimed at managing and protecting forest resources. These include efforts that have been ongoing for decades, in many cases, such as: (1) Forest Inventory and Analysis (FIA) surveys that assess forest productivity; (2) Forest Pest Management (FPM) surveys that report on forest health and insect, disease, and pollution impacts; and (3) Experimental Forests, Rangelands, Watersheds, and Research Natural Areas. Some of these experimental areas, which cover all major ecosystems and climatic conditions in the United States, have been in existence and monitored continuously for more than 80 years. This experience provides the Forest Service with an unequaled base upon which to build future programs and makes it uniquely qualified to provide the necessary leadership in examining climate-induced changes in forested ecosystems. These existing

Forest Service programs can be built upon to address the effects of climate change and variability and the effects of altered atmospheric chemistry on forest productivity, health, and diversity.

In addition to long-term research programs, the Forest Service conducts numerous related activities in response to the following legislative mandates:

- The Clean Air Act, under which prevention of significant deterioration (PSD) of Air Quality Related Values (AQRV) is evaluated for Class I (wilderness) areas;

- The Wilderness Act;

- The Endangered Species Act;

- The National Forest Management Act, for which monitoring the effects of land and management activities is required;

- The National Forest Management Research Act; and

- The Forest Ecosystems and Atmospheric Pollution Act of 1988, for which research on air pollution and climate effects on forest ecosystems is required.

FOREST SERVICE APPROACH

A broad ecosystem viewpoint is essential when examining the multiple factors affecting forest resources. This viewpoint addresses a wide range of physical and chemical atmospheric variables as they interact to affect all components of forested ecosystems. Past efforts have focused on single stress factors. Future protection of forest resources depends on a long-term research effort committed to a broad-based understanding of natural-dynamics and anthropogenic effects. The Forest Service goal is to supply forest ecosystem managers with the information they need to address changes associated with multiple-stress factors on forested ecosystems, especially those due to climatic variability superimposed on existing pollutant stresses.

The following questions must first be answered in order to obtain information on the key issue of how forest and range ecosystems will change in response to observed and predicted changes in the physical and chemical climate.

- What are the physical, chemical and biological processes that regulate forested ecosystems by exchanging energy, water, carbon, and nutrients with the atmosphere (ecosystem process research)?

- What is the current status or condition of forested ecosystems with regard to their structure, function, stability and biogeochemical properties and changes in condition over time (monitoring)?

- What are the ways in which forested ecosystem processes are likely to respond to changes in chemical and physical climates (modeling)?

Survey and monitoring must be a first-priority consideration because of the insufficient data available on the current condition of forest ecosystems and on rates of change in forest condition. Appendix D outlines monitoring issues important to this effort. Secondly, if the processes of ecosystem-atmosphere exchange can be understood, predictions of forested ecosystem response to various scenarios of chemical and physical climate change will be possible. Thus, developing a process-level understanding of forested ecosystems has high priority.

Many of the biological systems or processes that are expected to respond to changes in global climate also respond to many natural stress factors, often with similar results. For example, both drought and air pollutants may cause a reduction in photosynthesis and growth. Short-term cycles of climate and other natural stresses, such as pests and pathogens, can affect forest growth. Short-term changes in biological systems or processes caused by global climate change may be subtle compared to seasonal or monthly changes caused by natural stress factors (e.g., a drought or a late spring frost), while over the longer term greater effects may be found. Thus, to understand completely the impact of global climate change on the biological system or process and to predict likely scenarios of forest response, the response of the system or process to natural stress factors must be understood and included in process-based models.

To understand how ecosystems will respond to global change, it will be necessary to understand how biological processes, species, and community complexes within ecosystems respond to change. This is important because even if a process, such as photosynthesis, is affected in more than one species, the species' impacts may differ in severity. A slight difference in impact between species may result in a change in competitive interactions.

Experience gained from decades of forest ecosystem studies shows that an extensive and intensive plot system is required to evaluate ecological responses to subtle changes in the atmospheric environment over time and space. Measurements will be broadened to include complete descriptions of forest conditions and will be expanded to the scale of small watersheds through landscape and regional scales.

In conducting research on forest ecosystems where stand age can exceed 400 years and stand conditions are highly variable, atmospheric interactions and responses within a specific range of time and place will be impossible to document without a commitment to long-term research.

Global change research must be conducted over a range of temporal and spatial scales to attain an integrated understanding of the behavior of ecosystems in relation to physical and chemical changes in the environment. While some forest-atmosphere responses may be addressed on an annual basis, other processes require study over periods as short as a day or an hour, or as long as the life cycle of the organisms involved. The types of research required to detect and understand global change require various spatial and temporal scales, and research approaches will depend upon the scales involved. Only by focusing on a variety of scales of time and space can the program detect subtle ecosystem responses to global change.

Similarly, research will be required over a range of spatial scales. For many studies, an ecosystem unit the size of a small watershed will be necessary to examine inputs, outputs, and mediating processes that affect forest ecosystem behavior. This size is comparable to that of forest management units; forest plots can be located within small watersheds and a focus on ecosystems at this scale will facilitate the application of research results into management of such units. Many studies may occur at a much different spatial scale, however, ranging from forest landscapes that include composites of stands and networks of watersheds, to individual trees or portions of the soil-plant-atmosphere complex. The Forest Service research program will develop an integrated organism-to-landscape level understanding.

Impacts on patterns and processes may be observable only at the landscape scale in response to climate changes. Patterns of climatic variables will shift in different directions. For example, precipitation patterns may shift 100 miles or more in response to changes in air mass tracks, while the transient snow zone may only shift a few hundred feet up slope in response to warmer winter temperatures. The scientific capacity of the Forest Service to make observations on such scales is only beginning to develop; therefore, considerable research must be undertaken to address the problem of observation on appropriate scales. Particular emphasis will be placed on changes in ecotones.

Landform and land use affect the structure of ecosystems. Changing climatic patterns will be superimposed on these existing landform and land use patterns. Species and communities will respond to the changing pattern. Plant species will shift ranges differently in response to changes in the pattern of the environment; the same may be true of stream characteristics (e.g., low flows and peak flows) and erosion that is driven in part by the hydrologic cycle, vegetation, and landform patterns. These pattern shifts may affect riparian and aquatic ecosystems at an expanded scale. Domestic and wild animal species will respond to these changes in patterns of physical and vegetative habitat. Studies of their responses must be at the appropriate scales. Changes in patterns of fuel moisture regimes and lightning frequency and seasonality, and consequently in fire frequency and severity, also will occur at the landscape scale driven by variation in climate. Insect and disease outbreaks also will change with climate variation. Disturbances such as those produced by fire, insects, and disease also will alter the vegetation complex, adjusting to a new equilibrium between climate and disturbance phenomena.

Because different climatic variables will not move uniformly in space, other important responses to climate change probably will only be characterized adequately at the landscape scale. Integration of remote sensing and Geographic Information Systems (GIS) and modeling capabilities will facilitate work on effects at large spatial and temporal scales. Database management systems to monitor and understand the changes and to predict the future will be developed.

Research will be supported by several types of modeling efforts. Issues to be considered in these modeling efforts are outlined in Appendix E. Traditionally, management-oriented models, including classical growth and yield models and hydrologic models, have been empirically-based. Empirical models (also called top-down models) are carefully validated with field data and lend themselves to management application. They are not well-suited for examining forest ecosystem processes, but they certainly are useful in applying scientific knowledge to management problems.

In contrast, process-based models are useful for examining the behavior of forested ecosystems. The mere attempt to construct conceptual process models often uncovers critical research needs regarding the function of ecosystems or their components. Process models (also called bottom-up models) may be used to describe the biological and physical processes governing ecosystem behavior and response to changes in environment. Because of their complexity and the difficulty of validating these models with field data, process models do not lend themselves easily to direct application in forest management.

Phenomenological models are intermediate between empirical and process models. They are based upon process knowledge but do not require extensive process detail, thereby representing process phenomena in a simplified manner.

However, phenomenological models may use many empiricisms. Phenomenological models are particularly useful in bridging the gap between process and empirical models because they can convey essential process information to empirical models that otherwise are insensitive to differences in processes.

For different applications, separate model types will be required. Some models will have direct application in management; others will be useful in conceptualizing and synthesizing process research; and some will have applications to policy. These models should be developed during the early stages of data collection and should serve as the framework for monitoring and process research. The purpose of understanding the processes in forest ecosystems and the ability to model or predict the future is to provide forest managers with the best information with which to plan for resource management. Resource Planning Act Assessments and forest plans represent critical end points. Understanding processes and modelling will include expressions of uncertainty in the forecasts and will be fully compatible with social and economic models.

FOREST SERVICE GLOBAL CHANGE PROGRAM ELEMENTS

The FSGCRP stresses the importance of forest ecosystems in the whole scheme of global change and an ecosystem approach to observing, understanding, and predicting global change relationships. Six broad activity categories are included: (1) effects of the atmosphere on ecosystems; (2) effects of ecosystem changes on the atmosphere; (3) assessment of long-term changes; (4) ecosystem modeling; (5) response strategies; and (6) policy analysis.

The proposed FSGCRP centers on the U.S. Global Change Research Program element concerned with Ecological Systems and Their Dynamics, but also includes significant contributions under CEES Science Elements concerned with Climate and Hydrologic Systems, Biogeochemical Dynamics, Earth System History, and Human Interactions. Seven program title descriptors for the Forest Service Program, as they relate to the CEES program priorities through the seven CEES scientific elements listed previously, are described below. In addition, monitoring and modeling are identified as important cross-cutting activities that overlay the ecologically described titles.

The national plan for research on global change places climate and hydrologic systems as the highest priority for research. The USDA Program and Forest Service Global Change Research Programs place ecological systems and dynamics as highest Department and Agency priority. This ranking is consistent with the mission of the USDA and the Forest Service.

Forest Service Program Element:
<u>Terrestrial Vegetation, Life Histories and Distributions, and Community Compositions</u>

CEES Science Elements Addressed:
Ecological Systems and Dynamics
Earth System History
Human Interactions

Forest Service Program Objectives:

The processes by which species composition and distribution change will be the focus of this research. Particular emphasis will be placed on ecotones, where sensitivity is greatest and change is most likely to occur. Also, changes in land use patterns will be included.

Observations of species composition and biomass, age, health, and productivity in ecosystems and along ecotones will provide a database of current distribution and composition. Long-term monitoring of the plots established in this program element will provide a basis of assessing change, either from natural variability or from anthropogenic stress. Dendrochronology will be used to establish a historical base of forest health and productivity. Controlled experiments for specific cultivars across ecotones and along climate gradients, either elevational or latitudinal, will provide data on genetic resilience to stress and adaptability to changing environments. These measurements of morphology, structure, genetic base and phenology will be supported by measurements of the physical soil, atmospheric, and micro-organism properties.

The data from this research will be used to assess cause and effect relationships. The mechanistic stand development models generated under the program element on energy, carbon, water and nutrient cycling will be expanded to the landscape scale in this problem.

Forest Service Program Element:
<u>Water Quality and Quantity, Erosion, and Sedimentation</u>

CEES Science Elements Addressed:
Climate and Hydrologic Systems
Ecological Systems and Dynamics
Human Interactions
Earth System History

Forest Service Program Objectives:

Focus of this research is on determining how water resources will be altered as a result of global change. Changed precipitation, snow pack establishment, and snow melt timing interact with the vegetative components of the ecosystem and with the water courses that collect the water.

Water quantity and quality are in a dynamic equilibrium with the land structure and the ecosystem. Disruption of this equilibrium, and the processes by which a new equilibrium is established, will be a major component of this program element.

Experimental watersheds in forest and rangelands have monitored water yield and quality on manipulated and controlled watersheds for more than 50 years. This observational system must be continued and enhanced in order to establish baselines and trends in water supply. Existing broad spatial coverage observational systems are limited in regions of low population density - the headwaters of our water supply. Some components of the hydrologic cycle, e.g., evapotranspiration, groundwater recharge, and precipitation, are not easily measured over large areas. Valid results from the general circulation models (GCMs) require realistic measurements of water balance.

Coupling mechanisms between the atmosphere, land surface, and the hydrologic cycle will be studied. Also, the mechanisms in which small scale microclimate processes and the general circulation interact to produce variations in water supply will be investigated.

Regional process-driven hydrological models for forest and rangeland watersheds will be developed and coupled to the GCMs to provide better prediction of water quantity and quality.

Water supply is one of the dominant public policy issues in arid regions of the country. Understanding the processes governing water yield and water quality relationships with the terrestrial ecosystem, climate, and the solid earth is crucial

to predicting future water resources. This program element is highly relevant to the goals of the CEES plan in that hydrologic systems are a vital component of the atmospheric models. Scientific merits of the plan on observing, understanding, and predicting watershed processes are high. This program element will build on existing research within the Forest Service.

Geomorphological studies of historical river and lake systems, especially in the arid and semiarid climates, can be very helpful in determining past climate influences on ecosystems.

Forest Service Program Element:
Energy and Biogeochemical Cycles

CEES Science Elements Addressed:
Climate and Hydrologic Systems
Biogeochemical Dynamics
Ecological Systems and Dynamics

Forest Service Program Objectives:

Research emphasis will be on the linkages and interdependency between the ecosystem cycles and global change. This program element will encompass all major ecosystems and climates that contain important natural resources, such as timber, water, rangeland, wildlife, and recreational resources.

Monitoring will take place on the existing 83 Experimental Forests and Rangelands and 200 Research Natural Areas of the Forest Service. Observations of carbon, water, sulphur, nitrogen, and nutrient cations will be made in the soil, different plant parts above and below ground, and the atmosphere adjacent to the plants to determine material fluxes and storage. Simultaneous measurements of atmospheric and soil physical and biological variables will be made in order to understand the environmental forces and controls on nutrient cycling and retention. Both in-situ field experiments of complex ecosystems and controlled experiments in open top chambers and greenhouses will be used to determine responses to altered physical environments involving photosynthesis, carbon allocation, and water balance within plants and ecosystems. Gradient studies, either altitude or latitude, will be used to simulate climatic variations.

Mechanistic models for individual plants and specific ecosystems will be developed that describe the processes of carbon, water, nutrient cycles, space storage, and allocation. These models will be environmentally driven so that they can be coupled to the GCMs.

This program element is vital to understanding and predicting the structure and composition of future ecosystems. It will build on the current research program to develop the knowledge required to predict future forest and rangeland resources.

Forest Service Program Element:
Aquatic Ecosystems and Wetlands

CEES Science Elements Addressed:
Climate and Hydrologic Systems
Biogeochemical Dynamics
Ecological Systems and Dynamics

Forest Service Program Objectives:

This research will focus on the chemical and physical changes in aquatic ecosystems and the processes of how those changes affect aquatic life.

Monitoring of the chemical and physical properties of aquatic ecosystems will be on both natural and manipulated aquatic habitats. Of

concern here are the water temperature, biological oxygen demand, trace chemicals such as nitrogen, toxics, and acids, change in stream flow, and the species composition and abundance of aquatic life.

Research will focus on how the aquatic environment influences reproduction, growth, and survival of individuals, and how different levels in the food chain respond to stress. This research also will focus on determining the input-output budgets of nutrients. Methods to predict the budgets of key elements and their influence on aquatic species will be developed.

Aquatic ecosystems are as important as terrestrial ecosystems and are equally complex. This program element emphasizes an ecosystem and multiple stress approach to determining the effects of global change on aquatic ecosystems.

This program element will build on current contributing research. Cooperation with domestic federal and state fisheries agencies and with university scientists has been a strong component of the current program.

Forest Service Program Element: Insects, Pathogens, and Microbes

CEES Science Elements Addressed:
Ecological Systems and Dynamics
Biogeochemical Dynamics
Human Interactions

Forest Service Program Objectives:

Insects and diseases are major disturbances in ecosystem dynamics. Insect and disease epidemics also may serve as early warnings of changes in ecosystems. Understanding how pests shape the ecosystem to accelerate responses to global change and how global change will alter the patterns, intensity, and frequency of insect and disease outbreak is of highest priority. Equally important is how global change will influence the soil microbes, small soil animals, and the nutrient cycle. The scientific merits of this program element are very high in that it will contribute significantly to understanding disturbed ecosystems.

The research will focus on how global change influences the frequency and severity of insect and disease outbreaks. The importance of these outbreaks as a disturbance in the ecosystem and how those disturbances accelerate ecosystem change from one equilibrium to another also will be emphasized. Research will address the direct effects of global change on pest organisms as well as how insect and disease organisms function secondarily to influence stressed host species.

This program element also will focus on changes in the role that microbes and small soil animals play in breaking down large complex organic molecules into smaller mineral nutrients, which are then available for uptake by plants. Studies of the sensitivities of the mechanisms of nutrient cycling by microbes and small soil animals to global change will be given priority. Of special interest will be the role and interactions of mycorrhizal fungi and other organisms in the rhizosphere with host and associated environments.

Monitoring of forest health and identification of insect and disease outbreak is an ongoing program. This activity would be supplemented through more intense monitoring to provide the database for mechanistic studies. There is also a need to identify changes in insect and disease outbreak severity that can serve as indicators of environmental changes. Monitoring of decomposition rates and the activity levels of the microbes

and small soil animals will be necessary in order to quantify nutrient cycling.

Mechanistic models that couple climate to soil nutrient budgets and the activity of soil organisms will be developed. Also, models of insect and disease disturbance on ecosystem structure and composition will be developed. In addition, interactions between people and insects/diseases, such as suppression activities, are sensitive to climate and need to be better understood.

Forest Service Program Element:
Fire Severity and Occurrence

CEES Science Elements Addressed:
Climate and Hydrologic Systems
Biogeochemical Dynamics
Ecological Systems and Dynamics
Earth System History
Human Interactions

Forest Service Program Objectives:

Wildfire and prescribed fire occurrence and severity are controlled by weather and the amount and structure of the vegetation. The frequency and severity of drought, epidemics of pests and diseases within the ecosystem, and changes in humidity and winds are expected to vary with global change. All of these factors will contribute to major changes in the amount and distribution of combustible biomass. Fire is a major disturbance in ecosystems today and is expected to be a greater influence as a result of global change. The combustion of biomass fuels on a global scale makes a major contribution to the concentration of important "greenhouse" gases and particulate matter in the atmosphere. Fire and atmospheric sciences research will focus on the changed frequency and severity of fire weather, the processes of change controlling the transition from the current equilibrium between climate and ecosystems to a new equilibrium, and the production of trace gases and particulate matter, which is one of the feedback mechanisms contributing to the atmospheric chemical composition.

Data from fire-scarred trees and petrographic analyses will provide a historic record on fire frequency. Coupling these data with dendroclimatological and pollen data will give a history of fire in transitional ecosystems and climate relations. Recent fire occurrence, weather, and land use activities will provide data from which anthropogenic fire can be separated from natural fire.

Understanding the role of fire in ecosystems will provide information on how fire shapes the ecosystem and how the ecosystem recovers from major disturbances. Changes in land use pattern when fire is used to bring about change and the resultant productivity of the land will be investigated.

Models to predict the emissions from fires will be developed which are based on weather, and the physical structure, quantity, and chemical composition of different ecosystems. Direct measurements of emissions of important chemical species contained in smoke from wildfires and prescribed fires will be made to validate the models.

Fire is a major disturbance in ecosystem dynamics. Understanding how fire shapes the ecosystem to accelerate response to global change is of high priority. Because of the accelerated feedback of carbon and other emissions to the atmosphere, the development of models and techniques to quantify the release of trace gases and particulate matter from fire and the contribution of these materials from a radiative energy balance standpoint once released into the atmosphere is of equally high priority. The scientific merits of this program element are very high in

that it will contribute significantly to understanding disturbed ecosystems, and to quantifying the sources of trace gases and particulate matter from fires. The Forest Service has strong cooperative research activities with European, Australian, and Canadian research groups, as well as with scientific groups within the United States studying global change issues.

Forest Service Program Element:
Wildlife and Domestic Species

CEES Science Elements Addressed:
Ecological Systems and Dynamics

Forest Service Program Objectives:

Research emphasis will be on determining the sensitivity to, and impact on wildlife and domestic species from global change. The research program will include life history strategies of individual species, animal population dynamics, competitive interactions for food (forage), and community dynamics under altered environments. Attention will be given to threatened and endangered species.

Monitoring within this program element will concentrate on reproduction, growth, survival of individual species and populations, competition, species composition and species abundance within the ecosystem.

Understanding how global change will influence the size, shape, and distribution of habitat and how species will respond to these changes is a major focus of this problem. Changes in food and cover availability alter migration routes and affect intra- and inter-species competition. This manifestation of reduced forage quality in plants under altered temperature and precipitation is unknown, as are consequences of wild or domestic grazing, given a forage supply of lower quality. It is necessary to understand how biodiversity will be affected. Methods to predict habitat change will be developed. Models of population dynamics and competition, and changes in migratory habits will be developed.

This program is vital to research on terrestrial ecosystems in that wildlife and domestic animals are an integral part of the healthy functioning of ecosystems. Global change alterations in the productivity of ecosystems will affect the carrying capacity of forests and rangelands. Cooperation with federal and state game and fish agencies has been a part of this current contributing research program since its inception.

RESEARCH TO SERVE THE PUBLIC AND FOREST MANAGER

Results from each of the program elements listed above will provide the scientific knowledge required to address management issues under a changed physical and chemical climate. New information will enable resource managers to do the following:

- Determine the changes in species distribution and forest composition resulting from air pollution and climate change effects;

- Predict growth and yield of commercial tree species, and as a result, future timber supply under a changing physical and chemical climate;

- Predict the quality of forest products and therefore their economic value under a changed climate;

- Predict changes in habitat and carrying capacity of rangelands for game, non-game, and managed animals as a result of climate change;

- Predict future water supply and quality in a changed physical and chemical climate;

- Predict changes in sediment load in water courses resulting from climate change;

- Predict changes in habitat for endangered species as a result of climate change;

- Predict changes in recreational opportunities, particularly in wilderness as a result of climate change;

- Predict the changes in fire frequency and severity and therefore be able to estimate the future protection required; and

- Predict the changes in severity and intensity of insect and disease outbreaks resulting from physical and chemical climate change.

These Forest Service Global Change Research Program focused goals are consistent with our continuing research goals to:

(1) Provide long-term technical input to policy questions;

(2) Maintain productivity, health, and diversity of Forest Service lands, commercial forest lands, wildlands, and non-industrial private forest lands;

(3) Provide international forestry leadership in addressing forest/atmosphere interaction problems;

(4) Provide methods to determine the nature and magnitude of changes in forests and related ecosystems to climatic variables as well as to determine causality; and

(5) Develop an information base for the public and land managers to evaluate future options and develop land management plans.

The health of forests is determined by the status of vegetation, soils, water, and animal populations. Forest health or condition can be influenced by atmospheric pollutants. Forest productivity can be optimized by appropriate resource management and silvicultural practices that minimize disease, insects, and fire in order to increase growth. The forests existing today have grown in and adapted to a physical and chemical climate very different from that which currently exists or what is expected to occur in the near future.

To meet the challenge of maintaining forest productivity, health and diversity in the face of global change, the Forest Service stresses the importance of increasing our understanding of the interactions between all components of forested ecosystems and the atmosphere. To meet the impact assessment, response strategy, and policy approach questions involved with global change, the Forest Service stresses the important role forested ecosystems must play.

Forest Service Program Management Structure:

Forest Service research functions under a distributed management structure with national coordination and direction provided by the Washington Office to eight regional Forest Service Research Stations and the Forest Service National Forest Products Laboratory. The eight regional Forest Service Research Stations are: Pacific Northwest (PNW), headquartered at Portland, Oregon; Pacific Southwest (PSW), head-

quartered at Berkeley, California; Intermountain (INT), headquartered at Ogden, Utah; Rocky Mountain (RM), headquartered at Fort Collins, Colorado; North Central (NC), headquartered at St. Paul, Minnesota; Northeast (NE), headquartered at Radnor, Pennsylvania; Southern (SO), headquartered at New Orleans, Louisiana; Southeast (SE), headquartered at Asheville, North Carolina; and the Forest Products Laboratory at Madison, Wisconsin.

When the Forest Service Global Change Research Program was established, it was recognized that the ecological scales of interest extended to a range that was larger than the traditional Station boundaries. Therefore, the FSGCRP formed four regional research cooperatives, headed by Program Managers. These regional FSGCRP cooperatives are: Pacific Coastal (PNW & PSW), Interior West (INT & RM), Northern (NC & NE), and Southern (SO & SE). The map on the frontispiece shows the regional research headquarters, the geographic areas they cover, and the regional cooperatives. In addition to the four ecosystem based cooperatives, the FSGCRP includes a National Forest Health Monitoring Program (FHM), and a Forest Products Program. This FSGCRP allows global change problems to be addressed at the scales of action that are required (regional responses will be critical to natural resource managers) while retaining segments of traditional management and reporting structures. Figure 3 illustrates the FSGCRP structure.

As previously described, the FSGCRP is entirely consistent with, and integrated in, the CEES USGCRP. The Forest Service has joined with other agencies of USDA in developing the USDA Strategic Plan for Global Change, and with other agencies in developing the relevant science elements in the USGCRP.

FOREST SERVICE GLOBAL CHANGE PROGRAM REGIONAL PROGRAMS

INTRODUCTION

The Forest Service Global Change Research Program will be composed of four ecosystem-based regional efforts, and assessment, monitoring, response strategy, and policy analysis activities. This will be a long-term research program that will investigate the impact of atmospheric change, including increased variability in climate, to forest and related ecosystems. A broad ecosystem approach will be employed to evaluate potential impacts at several levels of biological organization: cellular, individual, population, community and landscape. Because global change will impact resources at these various levels, particularly at the ecosystem level, many studies will integrate research on several of the CEES Science Elements and the Forest Service Program Elements. The complexity of potential response to global change on varied spatial and temporal scales will make modelling a necessary and integral part of the Forest Service Program for generating and testing hypotheses, making predictions, and integrating results into GCMs. In addition, this broad scope of research necessarily emphasizes the need for widespread monitoring of vegetation and ecosystem process to detect change. The current program will build on the existing long-term data bases generated from the Experimental Forests, Ranges, and Watersheds.

The structure of the program also provides the necessary framework to integrate comparatively short-term, or 3 to 4 year, studies of plant physiological response to atmospheric-related stress with long-term studies of ecosystem processes and forest and range productivity. The four regional programs are highly coordinated through this FSGCRP Plan, and a National Program Coordinator will insure that the regional programs maintain this high level of coordination. Further integration will be achieved by development of common protocols for portions of the research, establishment of standardized quality assurance procedures, and implementation of a national data base management system.

The regional programs are distinct because of the inherent differences in the resources at risk in each region. However, they are linked by certain common features. Each regional program will:

- Perform integrated ecosystem-level research;
- Address the CEES Science Elements and the seven Forest Service Program Elements;
- Orient toward studying changes in natural ecosystems and include human influences and interactions with changes;
- Involve efforts to understand how climate and air pollution combine to cause multiple stresses on vegetation;
- Exhibit concern about water and how global change might influence the availability and quality of water;

- Exhibit concern with disturbances, such as fire, insects, pathogens, and the associated ecosystem changes, and how global change is likely to influence such disturbances; and

- Strive to develop an understanding of the structure and function of ecosystems so that the consequences of future global change can be predicted.

There are regionally distinct aspects of the program as well. The four regional subdivisions are the Northern, Southern, Interior West, and Pacific Coastal. The resources managed by the Forest Service in each are not only regionally distinct, but are subject to very different types of stress or potential stress. The Northern Region's main concern is how the interaction of global change and pollution stress will interact to affect forest health. The Southern Region has certain pollutant levels among the highest in the United States and a population density that is infringing on natural resources. Their focus is on the impact these stresses will have on timber production, since almost half of all the timber used in the United States is produced in this region. In the Interior West Region of the United States, protection of wilderness areas and availability of water resources are very important. If global change limits water availability, severe shortages are expected in this region. Thus global change can cause a severe impact in fire management and natural landscapes of this area. The Pacific Coastal Region faces very diverse concerns about global change. In certain areas high concentration of pollutants threaten forest health; in parts of the region the timber industry is very important to the economy. The concern for the Pacific Coastal Region is compounded since it has a vast diversity of ecosystems represented.

Summaries of the four regional plans are provided in the following sections to show how each regional program relates to the seven science elements of the Forest Service Global Change Research Program. Also, detailed highlights of regional research goals are provided. Greater specificity will be found in Regional Program Plans, currently being developed, that will complement and update this FSGCRP Plan. The following sections introduce the regional program components.

INTRODUCTION TO THE NORTHERN REGION

DISTINCTIVE FEATURES AND RESOURCES

The Northern Region Global Change Research Program will address concerns about the future of our forests in a changing physical and chemical environment. This long-term program will emphasize multidisciplinary research by both the North Central and Northeastern Forest Experiment Stations that focuses on the unique geographic attributes of the region with its major climate-related vegetation zones.

The grassland, deciduous forest, and coniferous forest biomes come together most strikingly in this region, reflecting the combination of strong gradients of moisture from west to east and temperature from south to north. Important ecosystems associated with this biomass include: prairie; oak-hickory forests; the hardwoods (mixed mesophytic, oak, and northern hardwoods) and the spruce-fir forests of the Appalachians; low elevation mesic northern hardwood-hemlock forests; dry sands with red and jack pine forests; upland forests of fir-spruce-aspen; and the northern lake region with its unusual mosaic of peatland black spruce forests. Each vegetation association also contains its own unique and diverse pattern of biotic communities and landform features. The vegetation changes in the Northern Region could be quite large, especially in the boreal forest area, because of temperature and moisture gradients, and because predicted climate changes over the region could be dramatic.

The forest resource in the Northern Region is intensively utilized for many different purposes. Population density is very high, particularly in the Northeast, and the co-occurrence of large populations and areas of forested land dictate an intimate association of people and forests. Both large and small municipalities rely on forested watersheds for water supplies, and some small towns and recreation areas use forests to recycle municipal and industrial wastes. Local economies are strongly tied to forest resources for uses such as recreation, aesthetic values, and extractive uses (e.g., maple sugar production, wood and fiber production). Several forest industries are closely tied to single species, for example, the particle-board industry is dependent mainly on aspen.

The Northern Region encompasses the major hardwood timber resource of the United States. The oak-hickory and northern hardwood forests of this resource represent major climate-vegetation tension zones. Consequently, these areas are likely to show the early consequences of climate change. The fragmentation of these forests due to urbanization and extensive agricultural areas will affect species' migration capabilities and the subsequent ability of some species to adapt to climate change. Displacement or loss of large areas of oak-hickory and northern hardwoods could have significant local, regional, and national economic consequences. Because the forest industry in these areas is strongly tied to specific species, changes in species composition would have direct impacts on the economy.

PRIORITY ECOSYSTEMS

A number of distinctive regional features exist that are likely to be impacted by global change. These include the Great Lakes and the many smaller high quality lakes and streams. Extensive areas of peats and cold organic soils are present that represent large potential sources of the greenhouse gases, i.e., methane and carbon dioxide, that could exacerbate global climate change. This region offers documentation of the last major climate change - the Wisconsin glaciation of 12,000 years ago. An excellent historical record exists in this area, and may provide important insight into effects of dramatic climate change. In addition, gradients in moisture (west to east), temperature (south to north), and pollutant deposition (generally from near natural background in the west to the highest levels in the United States in the east) exist across the region. These gradients, which occur across small geographic scales in the Appalachian and Adirondack Mountains, will permit comparisons.

The previously identified ecosystems important to this region include the grassland, deciduous forest, and coniferous forest biomes. The transition zones between these ecosystems, such as the forest-prairie transition zone, are of particular importance because of the potential impacts to these sensitive zones. In addition, the dense population of the Northern Region and the intimate association of people and forests dictates that urban areas, urban-forest transition zones, and human interactions are key areas of study.

UNIQUE RESEARCH CAPABILITIES OF THE NORTHERN REGION

The Northeastern and North Central Stations are well qualified to undertake this major, progressive, multidisciplinary research program. Both stations have contributed significant findings to the Forest Response Program of the National Acid Precipitation Assessment Program. This previous experience serves as a solid base on which to expand forest effects research. Some of the unique Forest Service research capabilities in this region include research programs in landscape ecology, carbon physiology, water quality-acid rain, host-pest interactions, biotechnology, forest management, forest economics, recreation-urban forestry, expert systems, and wildlife biology. This region also has: outstanding laboratory, open-top chamber, and greenhouse facilities; access through cooperators to additional open-top chambers and a biotron; experimental forests; research natural areas; and a Long Term Ecological Research (LTER) Station (Hubbard Brook), plus other nearby LTER stations not managed by the Forest Service for environmental monitoring. In addition, some of the country's most outstanding academic research institutions are located within the Northern Region boundaries. Forest Service scientists, working in cooperation with scientists from other institutions in the Northern Region, provide a strong scientific resource to conduct the research required to determine how human-caused changes in the physical and chemical climate are affecting the forest and related ecosystems of the northern United States.

SPECIFIC CONCERNS OF THE NORTHERN REGION

Terrestrial Vegetation, Life Histories and Distributions, and Community Composition

Northern Region research is heavily concentrated under this element. Subdivisions of research include: Physiological Responses to Multiple stresses, Biogeography and landscape Ecology, Disturbance and Forest Succession, Conservation Biology and Human Interactions.

Physiological Responses to Multiple Stresses

- Determine the fundamental effects of long-term exposures to ozone, acid precipitation, and altered water/temperature, under regimes of increasing carbon dioxide and UV-B, on physiological processes and subsequent growth of northern forest species. Major emphasis areas include carbon assimilation, carbon allocation, carbon-nitrogen relations, and water use efficiency.

- Examine changes in wood quality in response to global change.

Biogeography and Landscape Ecology

- Determine the climatic factors that account for the present landscape and predict how these factors contribute to species distribution.

- Evaluate historical relationships between precipitation, temperature, and tree growth in order to predict changes in soil-water regimes, nutrient cycling, and the impacts on species competition, survival, and regeneration. [Also addresses Energy and Biogeochemical Cycling Element]

- Determine the climate change vectors that are sufficient to cause the loss of forest species. Develop methods to detect changes in reproductive failure, pathogen virility, insect impact, etc. [Also addresses Insects, Pathogens and Microbes, and Wildlife and Domestic Species Elements]

- Develop methods to detect changes in community species composition and changes in species ranges. Develop and apply Geographical Information Systems (GIS) to monitor and display these changes.

- Combine GIS with successional models to consider both temporal and spatial changes, and apply population models under a variety of climatic regimes.

- Determine which of the species that respond to site disturbance, or to competitive opportunities, are the most likely to be first responders to climate change. Determine what conditions would preclude response. [Also addresses Insects, Pathogens, and Microbes, and Wildlife and Domestic Species Elements]

- Determine if sufficient genetic diversity exists within commercially valuable species to assure their continued survival and growth within their current range. Identify genetic varieties within commercial forest species that tolerate or thrive under climate change.

- Determine how global change will affect improvement and selection programs for quality hardwoods.

- Determine the conditions of climate change that would preclude flowering, fertilization, germ-

ination, establishment, or early growth of forest species.

Disturbance and Forest Succession

- Describe how weather patterns will be altered by global change, and predict how these weather patterns will affect tree and other species mortality through physical catastrophe (the occurrence and intensity of fire, storms, and flooding); biological catastrophe (epidemics of insects and pathogens); and human impacts (the use of forests for wood harvest and recreation).

- Evaluate the degree to which changes in disturbance patterns affect species occurrence, migration, and successional patterns.

- Predict effects of global change on flooding frequency and determine the relationship between bottom-land forest species and flooding frequency.

Conservation Biology

- Determine the effect of global change on biological diversity at local and regional scales, to include both forested and nonforested, aquatic, and terrestrial systems.

- Predict how biodiversity, or forest heterogeneity, will be affected by global change, land use, and land management.

- Determine the environmental requirements of rare, threatened, and endangered species. Predict what will happen to these species under various possible global change scenarios. [Also addresses Insects, Pathogens and Microbes, and Wildlife and Domestic Species Elements]

- Determine the effect of global change on compositional, structural, and functional diversity as components of biological diversity.

- Determine the effect of global change on species with limited distributions and small populations.

- Examine the potential effects of global change on gene pools of important northern forest tree species.

Human Interactions

- Evaluate the effects of global change on the human perception, use, and management of forested lands. Specifically, determine what forest attributes are perceived as necessary for an aesthetic and quality forest experience. Describe what weather regimes favor or discourage recreational use of forests.

- Examine the effects of global change on local and regional economies. How elastic are the various timber industries with respect to species change that may be caused by global change? What effect would global change have on recreational industries?

- Predict how global change will affect management options for forest land managers in the northern United States.

- Evaluate the effects of reforestation, especially in the urban forest, and other forest management practices in mitigating the build-up of carbon dioxide in the atmosphere. What level of direct absorption of carbon dioxide is provided by urban trees/forests, and under what conditions?

Water Quality and Quantity, Erosion, and Sedimentation

- Evaluate the hydrologic impacts of global change; specifically, effects on precipitation (including snow accumulation and melt), runoff, and soil moisture.

- Determine effects of global change on municipal water supplies, yield of both ground and surface waters, and quality of water flowing from forests.

- Develop accurate long-term forecasts of water availability and quality. Efforts must concentrate on improving accuracy of models by improving parameterizations for vegetation changes, soil behavior, snowfall, and snowmelt.

- Determine effects of global change on water temperatures and streamflow, evaluating effects of forest management practices and species compositions that may minimize evapotranspiration and provide maximum shading of streams.

Energy and Biogeochemical Cycles

Because research in the Northern Region is also concentrated under this element, further subdivisions were formulated. Energy and Biogeochemical Cycles is divided into the following areas: Soil Chemistry, Water Chemistry, Nutrient Budgets, Carbon Budgets, Urban Forests, and Effects of Forests on Global Change.

Soil Chemistry

- Determine the cumulative effects of global change on soil chemistry and tree/forest productivity and health along atmospheric deposition and temperature gradients in the Northern Region. For example, to what degree does soil acidification change soil nutrient pools, nutrient availability, litter decomposition, and tree growth and mortality? What is the relationship between climate change and levels of sulfate, nitrate, ammonium, and heavy metal deposition? How does sulfate, nitrate, ammonium and heavy metal deposition affect soil and tree chemistry in the Northern Region?

Water Chemistry

- Develop soil water/ion balance indices that reflect ecosystem stress due to global change. Specifically, what is the range of ion balance and soil water regimes in forest soils that defines normal and reduced tree growth?

- Predict climate-induced changes required to change northern peatlands from predominantly sulfur and nitrogen sinks to predominantly sulfur and nitrogen producers (in terms of precipitation supplies and streamflow leaving peatlands). [Also addresses Aquatic Ecosystems and Wetlands Element]

- Determine the climate-induced changes required to increase the availability of toxic trace elements in soil water and their export to streams and lakes.

Nutrient Budgets

- Describe the interaction between forest removal (clear cutting or whole tree harvesting) and global change, as it affects nutrient budgets and ecosystem processes in forests of the Northern Region. [Also addresses Terrestrial Vegetation Element]

- Predict the global change impact on the rate of forest floor mineralization, and determine how microbial populations respond. [Also addresses Insects, Pathogens, and Microbes Element]

Carbon Budgets

- Describe the combined influences of atmospheric deposition and climate change on the rate of carbon production or its allocation within structural components of forests in the Northern Region.

- Determine the effects of climate change on carbon budgets across important ecosystem tension zones (ecotones) in the Northern Region. Develop carbon budgets at regional or biome scales.

- Determine the capacity of current and potential forested areas in the northern United States to sequester additional carbon or reduce the release of carbon through more intensive management.

Urban Forests

- Examine the interactions between urban forests and global change. Describe the effects of global change on urban forests and examine how changes in urban forests interact with climate changes.

- Determine the capacity of urban vegetation to modify the micro- and meso-scale climates in urban areas.

- Evaluate the reduction in fossil fuel use that might be achieved by summer shading and winter wind breaks through the use of urban trees/forests.

- Develop management options that will minimize the effects of climate change on urban forests.

Effects of Forests on Global Change

- Determine the potential of Northern Region peatlands to exacerbate global change through evolution of methane to the atmosphere.

- Determine the degree to which current forest management practices affect global climate change.

<u>Aquatic Ecosystems and Wetlands</u>

- Quantify effects of global change processes and factors on the severity of chemical and physical changes in streams and their associated effects on freshwater fish populations.

- Determine how changes in moisture deposition and changes in temperature will affect aquatic ecosystems and wetlands in the northern United States.

- Identify systems which will be most sensitive to moisture and temperature changes and can be used as monitors or indicators of change.

<u>Insects, Pathogens, and Microbes</u>

- Determine how global change stresses affect microbe populations, microbe-produced products, mycorrhizal relationships, plant pathogens, and insects, and predict the associated impacts on forest productivity. [Also addresses Energy and Biogeochemical Cycling Element]

- Predict the climate conditions associated with changes in insect and pathogen populations from endemic to acute. [Also addresses Wildlife and Domestic Species Element]

- Determine soil water and nutrient conditions that will impair the population response of microbial populations.

Fire Severity and Occurrence

- Predict how global change will alter forest fire incidence and severity in the northern region. Specifically, how are humidity, days since precipitation, wind speed, and fuel moisture likely to change and how will these changes affect the incidence and severity of forest fires?

Wildlife and Domestic Species

- Determine the global change-induced conditions that will impair the survival, fecundity, and regeneration capacity of important wildlife species. Predict the effect of such conditions on wildlife energy budgets, and develop management practices designed to mitigate adverse effects.

- Determine the effect of global change stresses on mast production and its impact on wildlife species and populations.

- Determine the effects of changes in forest structure resulting from global change on wildlife habitat and population dynamics.

INTRODUCTION TO THE SOUTHERN REGION

DISTINCTIVE FEATURES AND RESOURCES

The Southeastern Forest Experiment Station and the Southern Forest Experiment Station have joined forces to address the impact of global change on forest ecosystems in the South. The questions of global change impact to forests in this region are particularly pertinent for several reasons. Industrialization of the United States dramatically affected the eastern seaboard, impacting southern forests several major ways: the presence of rapidly growing, commercial species led to heavy reliance on the South for timber; increasing population density and natural variability of the forests lead to increased utilization of this resource for recreational purposes; and increasing population density in combination with certain climatic patterns resulted in noticeable increases in pollution in the region.

The Southern Region produces almost half of the nation's timber and production capacity could be increased on many private forest lands. Forestry and forestry-related industry is the most important industry to the economy of the South. The productivity of these forests is also important for many other noneconomically-rated factors such as species diversity. The forests provide important habitat; over 50% of the threatened and endangered species identified for U.S. National Forests are found in this region.

The forests also are nationally important for recreation, fishing, hunting, hiking, and camping. Tropical forests in the region provide the unique opportunity to study not only the impact of a changing chemical and physical climate on forest, but also to study how land management practices such as harvesting and controlled burning impact climate.

Coastal and forested wetlands are being lost to urbanization and agriculture at a rapid rate. Temperature change and sea-level rise pose an even greater threat to these biologically diverse and valuable habitats. The South has the majority of coastal wetlands in the United States. More information on stress impacts is needed to protect these resources.

Pollution certainly plays a role in forest ecosystem dynamics, although there are questions and uncertainties. The deposition of sulfur and nitrogen is unquestionably highest in the areas downwind of the highly industrialized Ohio Valley. However, sulfur and nitrogen deposition have been steadily increasing in the South since the turn of the century. There is evidence that it may increase actions that could lower productivity. Ozone levels are among the highest in the South. This is primarily due to the stagnant air masses that hang over the South in mid-summer during the growing season. Although research has indicated damage to seedlings and branches of trees, ozone impacts must be studied on a stand level to provide estimates of regional impacts.

PRIORITY ECOSYSTEMS

Research in the Southern Region will emphasize the ecosystem as the organizational focus. A system focus ensures that the biological, chemical, and physical features of the environment are integrated. Linkages among the atmosphere, biota, soils, and water quality are necessary to develop this approach.

Many types of forests occur in the South, where over 70 percent of the land is forested. These include: montane, sub-montane, temperate and tropical. The composition and distribution of these forests are diverse, as is the potential stress they could be subjected to in the future. A current evaluation of relative risk will emphasize research in priority ecosystems.

The pine forest types of the piedmont and coastal region will be studied because of their importance in local, regional, and national economies. The major climate predictions for the future indicate that these forests will be impacted, altering species distributions and growth and yield. These forests are highly productive and are a major potential sink for greenhouse gases. Because of high temperature and low rainfall across the western edge of the region, forests are replaced by semi-arid chaparral. This large area at the edge of the ecotone provides a unique opportunity to study the impact of physical climate changes on forest health.

Montane spruce-fir ecosystems at the upper elevations of the southern Appalachians are ecologically distinct populations that could respond rapidly to environmental changes. Also, air quality monitoring has shown that these rural forests are exposed to high levels of some pollutants. These forests are also biologically diverse. Understanding how physical and chemical stress might impact them is needed to protect their resource values.

The tropical forests in the Southern Region are also a high priority for study because of the role of tropical forest conversion on the earth's climate. The high productivity of these forests indicates their potential sink/source role in the earth's carbon cycle. These forests also are biologically diverse.

Scenarios of climate changes vary, but all identify the South as a major resource at risk. Study must be undertaken to determine how changes in temperature, precipitation, carbon dioxide, and UV-B radiation will impact southern forest ecosystems before climate change effects can be evaluated.

UNIQUE RESEARCH CAPABILITIES OF THE SOUTHERN REGION

The South has the oldest, continuous studies of forest health and productivity in the United States. Research initiated through the Forest Service, Forestry Cooperatives, and forest industry provide an extensive network of study plots across the region with many decades of data on growth and yield, competition, nutrition, and genetics that will be invaluable for the study of regional impacts of global environmental change on forests. We also have a number of Research Natural Areas on our National Forests and several Long-Term Ecological Research sites, supported by the National Science Foundation.

The 52 year-old Institute for Tropical Forestry in Rio Pedras, Puerto Rico has a research area of 28,000 acres ranging from tropical moist to cloud forest and across to research on the eight com-

monwealth/state forests ranging from tropical dry to tropical moist zones.

The Forest Service in this region has made major contributions to the National Acid Precipitation Assessment Program's Forest Response Program. State-of-the-art technology has been developed to determine how air pollutants impact southern tree species. Also, many excellent research facilities and outstanding scientists are located at agencies, institutions and industry in the Southern Region.

SPECIFIC CONCERNS FOR THE SOUTHERN REGION

Terrestrial Vegetation, Life Histories and Distributions, and Community Composition

- Quantify the effects of tropical deforestation on global change.
- Describe interactions between environmental stresses and species diversity, reproductive success, and genetic variability.
- Determine how harvesting, conversion, and other management practices, including fire, influence forest-atmosphere interactions.
- Evaluate genetic variation for tolerance to specific stresses to identify and develop tolerant families and/or predict changes in unmanaged ecosystems.
- Describe the effects of global change on the phenological response of plants.
- Identify mechanisms of inter- and intraspecific interactions, both above and below-ground, considering trees, shrubs, and herbaceous species.

Water Quality and Quantity, Erosion, and Sedimentation

- Evaluate the effects of intensive forest management practices on long-term soil fertility and nutrient cycling in relation to atmospheric deposition.
- Evaluate alteration of streamflow amount and timing from forested watersheds due to climate change and variability.
- Determine impact of water availability on forest growth and landscape patterns.
- Determine the effects of increased erosion and sedimentation in relation to forest practices, i.e., harvesting and roads.
- Determine effects of global change and toxic pollutants on water quality.

Energy and Biogeochemical Cycles

- Determine the effects of climate change and UV-B radiation on carbon fixation, allocation, and growth, above and below-ground.
- Identify effects of ozone, carbon dioxide, and acid deposition on carbon fixation, allocation, and growth, above and below-ground.
- Determine mechanisms of ozone uptake and adsorption, and the subsequent impact on forests.
- Determine the extent of soils potentially sensitive to acid deposition.

- Determine mechanisms of water utilization efficiency under pollutant impact, especially carbon dioxide and ozone.

- Determine the magnitude and seasonality of specified hydrocarbon emissions from major forest species, types, and soils.

- Describe relationships between changing deposition, site chemistry, plant nutritional response and litter decomposition on site quality.

Aquatic Ecosystems and Wetlands

- Determine the effects of global change on extent and composition of forested wetlands.

- Determine the effects of global change on cold water fisheries. Link with major efforts of the U.S. Fish and Wildlife Service.

Insects, Pathogens, and Microbes

- Determine the effects of changes in atmospheric chemistry and climate change on microbial regulation of nutrient transformation.

- Determine the interactive effects of ozone, carbon dioxide, and climate on the susceptibility of forests to major pests such as southern pine beetle, hardwood defoliators, and fusiform rust.

- Evaluate changes in rust disease dynamic/-epidemiology under altered water and temperature regimes.

- Evaluate patterns of major insect and disease species in the South under elevated ozone (greater than 50 ppb hour average) and changing climate.

Fire Severity and Occurrence

- If monitoring identifies increased fire severity or occurrence, research will be initiated.

- Evaluate the impact of controlled burning on the atmosphere.

Wildlife and Domestic Species

- If monitoring indicates it is a problem, evaluate the effects of changes in chemical constituents of the atmosphere on wildlife habitat, especially for threatened and endangered species.

Monitoring

- Design and implement a long-term monitoring program to evaluate status and trends in the condition of forest ecosystems, in relation to a changing forest environment.

- Identify and monitor sensitive bioindicators of global change and pollutant impact, with emphasis on Air Quality Related Values (AQRVs).

- Establish and continue a system of monitoring sites relevant to southern forest ecosystems for changes in carbon dioxide, ozone, UV-B radiation, wet and dry deposition, and meteorology.

- Evaluate the use of remote sensing technologies for detection of ecosystem response to physical and chemical climate change.

- Develop techniques and approaches for interfacing atmospheric processes and ecosystem processes.

- Determine long-term trends in the amount and chemistry of streamflow from forested watersheds, in relation to physical and chemical changes in the environment.

Ecosystem Modeling

- Initiate modeling to guide research activities and integrate information collected with the region on global change research.

- Modify and improve hydrologic models for predicting water balance and streamflow in response to climate change.

- Develop/refine process-based stand dynamics models for southern forests.

- Develop/refine current, empirical growth and yield models to incorporate atmospheric changes and silvicultural practices for pine and hardwoods.

- Develop techniques and approaches for interfacing ecosystem models at different spatial and temporal scales.

- Develop integrated ecosystem models of hydrology, productivity and biogeochemistry.

INTRODUCTION TO THE INTERIOR WEST REGION

DISTINCTIVE FEATURES AND RESOURCES

The Interior West Region includes the Intermountain and Rocky Mountain Experiment Stations. This territory encompasses the backbone of the Rocky Mountains from the Canadian border to Arizona and New Mexico, including high mountains, large valleys, interior cold desert basins and the Great Plains. Climates presently vary from moist maritime in the Inland Empire, to alpine in high country, to hot desert in the southwest, to harsh continental in the Plains. Natural vegetation varies from warm Mojave Desert types to alpine. The Interior West Region includes an immense diversity of biotic communities. Large tracts of public land are either designated or proposed as wilderness areas, representing a unique biologic resource where management objectives are to maintain biodiversity with minimal human influence. Bristlecone pine trees, the oldest living thing on Earth, grizzly bears and cutthroat trout are but a few of the unique biological elements that share this vast area with humans.

Western climates are geographically very diverse. Because of the topography, climate change predictions by general circulation models are particularly uncertain in this region and are unlikely to improve substantially in the next 10 years. However, because the air is reasonably free of anthropogenic pollution on a regional basis, pollution will not confound changing climates to the extent it does in many other parts of the United States. Ecosystems in this region have evolved under stress to a greater extent than those in other regions. Drought, severe cold, heat, and strong winds are not uncommon, providing some stress tolerance in natural landscapes.

The Interior West Region and its forested mountains generate most of the water available to support midwestern agriculture, growing populations in western sunbelt cities, pristine wilderness, and some highly productive timber lands. Climate change, consisting of different temperature patterns and altered precipitation, has significant potential to disrupt this water supply. Natural resource industries such as livestock ranching and timber harvesting are directly dependent on ecosystem productivity. Therefore, they also are closely dependent on climate. Ski areas and other developed recreation industry depend on a reasonably predictable climate delivering snow and sunshine at their expected times of the year. Economic consequences of climatic dislocation could be severe for this sector of the country. The deserts of Arizona and Nevada, the mountains of Colorado, New Mexico, Utah and Wyoming, the Great Plains and the forests of Idaho and Montana are unique places where natural processes dwarf the work of humans. Recognition of these values led to the establishment of large tracts of Wilderness and National Parks. Growing global population and industrialization now have the potential to alter climate in these pristine areas.

Altered drought or desertification patterns, loss of biodiversity, altered fire frequency, intensity and location, increased stress from insects and disease on trees, reduced carrying capacity of the rangelands, and loss of valuable riparian forests represent but a few of the potential management

concerns in this region. Management must develop intelligent and prudent responses to these possible consequences. First, managers need to recognize that climate is not a stable variable. They must consider the consequences of their actions in this light. Boundaries should not be artificial, genetic diversity should be maintained, species migration corridors should be developed, and so forth.

Much of this action requires more information than is currently available on climate and ecosystems. The Interior West plan calls for a broad program of collaboration on interdisciplinary and complex research, focusing on an array of scientific studies on water. These will improve the ability to predict the amount, timing, and quality of water generated from mountain snowpacks. The research will determine the economic value of increased and decreased flows and will improve management of riparian zones.

The negative impacts of insects, diseases, and fire may increase under an altered climate. Research will quantify relationships between insects, disease, and climate and aim to predict the consequences of global change. Fire is a related forest factor controlled by climate. Each of these factors cannot be separated but must be studied as multiple stresses. Perhaps most importantly, each of these factors driven by climate change can compound the effects on forest landscapes. Research must quantify these multiple influences and interactions and provide optimal strategies and prescriptions for management under the changing climate of the next century.

The Interior West Program involves model development, validation, and application throughout as a primary research tool. Modeling will be conducted to: 1) organize hypotheses, thereby summarizing the state of knowledge; 2) aid in the planning of research and allocation of resources; 3) accommodate linkages across scales; 4) represent forests and natural ecosystems to larger scale earth system modeling; 5) predict resource outputs under scenarios of a changed future climate; and 6) predict future landscape features by using GIS technology to link multiscale/multidisciplinary process and stochastic/empirical simulation models. Specific outputs from the Interior West Research Program will be forecasts of resource availability in the future as a result of climate change scenarios. These projections can be made on a national scale and will be inputs to Forest Service land management planning processes and Resource Planning Act (RPA) Assessments as well as program reporting. Should it be needed, national modeling coordination would be a natural role for the Interior West Program.

The Interior West Research Plan acknowledges the need to design a valid monitoring plan for use throughout the Western United States to detect ecosystem changes. Because of the vast land areas involved and the heterogeneity of ecosystems, the interior west devotes a significant research effort to monitoring. Research will address issues such as uniformity of measurement, data analysis, data archival, and logistic and resource constraints.

PRIORITY ECOSYSTEMS

Major ecosystems - desert, shrubs, grasslands, Pinon-Juniper (P-J) woodlands, Ponderosa Pine forest types, Mixed Conifer types, Douglas Fir types, subalpine type, and alpine tundra - are linked to elevation and often crowded into small areas, such as on mountains. They have seen significant changes, having experienced extremely active glaciation over the past millennia. The analysis of tree rings has provided an excellent display of the effects of past climate on long lived trees in the region. Analyses of bogs and

rat middens attest to major changes in vegetation occurring over the area in post-glacial times. Areas of earlier subalpine forest vegetation are now dominated by sagebrush and juniper, whereas previous alpine areas now contain productive mesic forests.

Another priority of the Interior West Region are the boundaries where different biological communities meet, in ecotones. Integrated ecosystem research is needed to study ecotones within the landscape, determine any direction to the changes constantly occurring in these landscapes, and determine what processes drive the changes. The important scientific question of how fine scale biological diversity interacts functionally to produce larger scale effects will be addressed by organizing ecotone research through the use of a GIS. A number of ecotones throughout the area of the Interior West Region will be studied. Priority will be placed on those junctures which are both sensitive to change and potentially related to a relatively few independent variables across a fairly broad geographic area. All ecotonal research will be multifunctional and done from an ecosystem perspective.

UNIQUE RESEARCH CAPABILITIES OF THE INTERIOR WEST REGION

This plan represents a coordinated Intermountain/Rocky Mountain research effort. The proposal builds upon the unique capabilities of the research staff of the two stations, the land resources of the region, experimental facilities managed by the stations, and numerous research cooperators. For example, five Long-Term Ecological Research sites supported by the National Science Foundation (NSF) are located in the region and attest to the recognition given university programs here. The National Center for Atmospheric Research (NCAR), funded by the NSF, is located in Boulder, Colorado. NCAR is an international focal point for atmospheric research and brings together the world community researching global change through computer networks and unique laboratory and atmospheric measurement facilities. Intermountain/Rocky Mountain cooperative links with NCAR will provide forest ecosystem expertise to work with NCAR's strengths in the atmospheric sciences.

This research also will be coordinated with other Federal agency efforts. Both Forest and Range Experiment Stations have a long and productive history of working with the Bureau of Land Management, Agricultural Research Service Geological Survey, NASA, and NOAA.

Both stations have long and rich histories of research on natural ecosystems in the territory. The stations maintain a series of experimental forests and ranges with a continuous data base, in many cases of 50 to 75 years. New sites include the Glacier Lakes Ecosystem Experiments Site (GLEES) established for the specific purpose of studying climate effects on the alpine/subalpine ecotone. Scientists at both the Intermountain and Rocky Mountain stations conduct ecological, plant stress, genetic, watershed, range, silvics, wildlife, fisheries, fire, snow, planning, recreation, economics, air pollution, and climate research.

SPECIFIC CONCERNS OF THE INTERIOR WEST REGION

Terrestrial Vegetation, Life Histories and Distributions, and Community Compositions

- Predict changes in species composition and distribution resulting from global change.

- Determine the interrelationships between species migration and biogeochemical cycling, particularly carbon, along a climatic gradient.

- Quantify the influence of air pollution and changing climate on wilderness-like ecosystems, especially high elevation and other ecosystems remote from human influences.

- Determine and evaluate the consequences of climatic changes on critical habitat parameters necessary for threatened and endangered plant species survival.

- Determine and evaluate the consequences of climatic changes on conservation forestry systems in the semi-arid Great Plains.

- Determine the genetic potential of important tree and shrub species to cope with changing environmental parameters.

- Compare measurements of the carbon balance of trees in old growth and young growth sub-alpine forest ecosystems in order to improve the ability to predict impacts of global change on tree survival and health, and net effects on the global carbon balance.

- Develop economically and environmentally sound management strategies (i.e., silviculture systems) for manipulating forests to provide goods and services in view of the potential for global change.

- Develop and apply models capable of aggregating evolving research information about ecosystem impacts of global change into Forest Service planning and resource output prediction modeling. National resource projections, in turn, need to be incorporated into similar global resource projections in the face of global change. These projections also need to reflect forest management capabilities for adaptation and mitigation of global change.

- Identify a technique that can efficiently establish baseline forest conditions and detect changes at the landscape level, and evaluate the validity of landscape level process models, in a statistically defensible manner.

Water Quality and Quantity, Erosion, and Sedimentation

- Develop improved models linking evapotranspiration and cumulative watershed effects to predict water yield at the stand level. Develop logical links through GIS to model water yield at the forest and landscape level.

- Predict the effects of climate change on factors governing water chemistry. Evaluate these factors along with cumulative effects from multiple land users.

- Predict the consequences of global change and forest management on high country contributions to future water quantity, quality, and timing in the Arkansas, Colorado, Columbia and Missouri river systems.

- Couple habitat types and transitory snow through GIS with a sediment yield model to predict slope stability change under scenarios of vegetation type conversion and climatic stresses.

- Develop a riparian zone sensitivity model based on hydrologic response, including streamflow and groundwater characteristics, to global change. Acknowledge the major role riparian vegetation plays in ecosystem functions. Identify the management implications resulting from this sensitivity.

Energy and Biogeochemical Cycles

- Observe and predict how altered climate variables (i.e., temperature, wind, precipitation, and humidity), soil moisture, and UV-B radiation will affect biological changes and carbon partitioning within ecosystems, and the ecotonal areas between them, through manipulative experiments. Old growth forests will be especially important.

- Characterize the exchange of energy and trace gases (O_3, NO_x, CO_2, CH_4) and their feedbacks between the atmosphere, the cryosphere, and ecosystems (including ecotonal areas between ecosystems).

- Develop Soil-Vegetation-Atmospheric-Transfer (SVAT) models to represent ecosystem characteristics in a concise yet realistic manner to models of the atmospheric planetary boundary layer ultimately for use by GCMs.

- Develop and verify models that simulate advective effects of local to microclimate scales particularly between landscape units.

- Determine, through the establishment of a few comprehensive monitoring sites, the extent of current climate change and its influences in the Rocky Mountains.

- Determine what techniques can efficiently establish baseline forest conditions and detect changes at the landscape level, and evaluate the validity of landscape-level process models in a statistically defensible manner.

- Develop models capable of describing ecosystem stability in the face of global change.

Aquatic Ecosystems and Wetlands

- Relate potential hydrologic changes resulting from climate change to fisheries habitats.

- Determine how a changing climate might affect the habitat and vulnerability of threatened and endangered native fish.

Insects, Pathogens, and Microbes

- Assess potential changes in epidemiology and importance of forest pests (bark beetle, DF tussock moth, western spruce budworm, armillaria, blister rust, mistletoe) in a changing climate.

- Determine the interactions between plant stress and pest success. Begin with pilot model interactions: 1) Budworm/Douglas fir - to study effects of changing nutrition; 2) Armillaria/pine - to study effects of climate stress.

- Assess and model the effects of climate induced changes in pest impacts on resource values. Develop new political/social/economic paradigms relevant to these resource value changes.

- Determine the roles of selected non-pest microbes and invertebrate faunas in maintaining the health and viability of ecosystems, and predict the effects of climate change on these roles.

Fire Severity and Occurrence

- Develop models to predict the potential for large fires and to predict their spread and energy release characteristics.

- Develop models to predict the release of important greenhouse gases as functions of fuel chemistry and physical properties.

- Evaluate the consequences of alternative fire policies and changing ecological landscapes using global climate models with dynamic inputs from fire emissions and gas exchange models.

- Modify guides for fire behavior, fire danger rating, and prescribed fire to enhance fire management decision-making in light of expected global change.

- Develop an integrated model for predicting probable changes in fire's role in ecosystem dynamics in the Interior West.

Wildlife and Domestic Species

- Determine the sensitivity of domestic and wildlife species to changes in the quantity and quality of forage and habitat across the landscape under a changing climate.

- Develop methodologies to predict population characteristics of an assemblage of wild animals, such as birds, rodents, ungulates, and reptiles, responsive to climate change.

- Identify the effects of climate change on critical habitat for threatened and endangered species.

INTRODUCTION TO THE PACIFIC COASTAL REGION

DISTINCTIVE FEATURES AND RESOURCES

The Pacific Coastal States Program is a collaborative effort between the Pacific Northwest and Pacific Southwest Experiment Stations, which include Alaska, Washington, Oregon, California, and Hawaii. Because global change could cause major changes in Pacific ecosystems, ranging from extensive vegetation mortality and migration to changes in chemical cycling and hydrology, the program will focus on an ecosystem approach to understanding interactions between multiple stresses derived from climate change, air chemistry changes, and ecosystem processes. The approach will incorporate landscape and watershed-level research with smaller-scale studies of responses and response mechanisms. Individual studies will range from large-scale field research to detailed laboratory, chamber, and greenhouse studies. Modelling will have an integral role in this program, from helping to define objectives and hypotheses, to describing research results and predicting system responses to changes. Research from this region also will provide input to general circulation models on a national level. Monitoring is a critical component of this program, including: establishing a transect from polar to tropical regions to monitor change; use of data bases from existing monitoring stations on experimental forests, LTER's, and experimental watersheds; applying remote-sensing-based methods for evaluating fire characteristics, emissions, and monitoring; and predicting ecosystem change. New management strategies for mitigation of and adaptation to global change effects will be needed throughout the region.

The Pacific Coastal region is characterized by a broad geographical extent, a wide coverage of major climate zones ranging from polar to tropical, steep gradients in climate and elevation, and unstable terrain. These characteristics lead to a high diversity and heterogeneity of ecosystems with a concurrent large number of ecotonal areas. The region also has hydrologic extremes, ranging from desert to rain forest, with frequent droughts and floods, and high spatial and temporal variability in climate. Many of the region's ecosystems are heavily impacted by fire and air pollution. High population pressure increasingly effects wildland ecosystems and management priorities in many parts of the region.

Some of the nation's highest-valued forests occur west of the Sierra-Cascade crest from northern California into Alaska. These forests are important not only for timber, but for wildlife, recreation, aesthetic and conservation value (e.g., the importance of old-growth forests), and their impact on anadromous fisheries. The Pacific Coastal Region also has the highest biological diversity, both in species and in ecosystems, of any region of the country, and support large numbers of endemic, threatened, and endangered species and ecosystems. Water is a critical resource throughout much of this area, and impacts of global change on hydrologic regimes, ranging from desert, to rain forest, to permafrost, are of particular concern. Steep slopes, unstable landforms, and the value of water make the region particularly sensitive to changes in precipitation

amount, form (rain or snow), and timing. Other critical concerns in this region are fire protection and impacts of global change on fire frequency and severity. Effects of air pollution on forests, soils, and water quality in southern California have already been documented; impacts of this pollution on ecosystem processes and on climate change, as well as fire/air pollution interactions are just beginning to be understood. Potential effects of global change in this region are greatly confounded by the impact of rapid human population growth and urbanization -- from southern California to Puget Sound -- on forest ecosystems and forest uses and values.

PRIORITY ECOSYSTEMS

Research in the Pacific Coastal region will have an ecosystem focus because of the great diversity of systems. Seven major ecosystem complexes occur in the Pacific Coastal States region, providing a rich diversity of ecosystems for study. These are: polar, boreal, moist temperate, Mediterranean/dry temperate, desert, tropical, and alpine. To achieve the broad interdisciplinary approach needed, the Pacific Coastal regional effort will be concentrated in three critical systems: boreal forest, moist temperate forests, and Mediterranean/dry temperate forests and shrublands. Research on other ecosystems is lower priority, but will be conducted where feasible. Key issues in selecting the three top priority ecosystem complexes are discussed below.

Boreal forests and the boreal (taiga)-tundra interface are widely believed to be one of the most sensitive systems to global change, largely because of the importance of permafrost in determining forest distribution in these areas. Boreal forests have a large carbon pool (30% of total terrestrial) and high rates of carbon accumulation, so impacts of changes in distribution or carbon cycling in these forests on global change may be substantial. These systems are believed to be a major source and sink for greenhouse gases, whose fluxes could be altered considerably by major vegetation changes, changes in organic matter decomposition and accumulation, or changes in fire regime. Boreal forests also are important for their wildlife and wilderness values. Global change also may cause major watershed impacts, including alterations in yield of sediment and nutrients and changes in distribution of wetlands and riparian habitats. Because of the large land surface these forests cover on a global basis, there is tremendous international emphasis on Arctic research.

Moist temperate conifer forests, such as Douglas-fir/western hemlock/redwood types, are important because of their many values to society, including high timber production, anadromous fisheries, water supply and conservation, wildlife and aesthetic values -- particularly in old-growth forests. Old-growth and high volume forest stands are important for their large carbon pools in both standing biomass and forest floors. These forests also are notable for high biodiversity and for the importance of certain threatened ecosystems, such as coastal redwoods and port-orford cedar, that may be heavily impacted by global change. Emphasis will be placed on maintaining resource values, adapting to and predicting resource changes, and protecting threatened species.

Mediterranean/dry temperate ecosystems, such as chaparral and yellow pine types, cover vast areas in California and the inland West. Because of the high drought stress already characteristic of these systems, they are potentially highly sensitive to changing CO_2 levels, water regimes, and insect and disease stresses. Even the climate extremes of the 1980's appear to be causing substantial tree

and shrub mortality in some areas. Because the Mediterranean systems frequently border on high population areas, impacts of global change on water quantity and quality will be particularly critical. High levels of air pollution in many of these areas may interact with global change to alter stream chemistry, affect nutrient regimes and ecosystem processes, and affect trace gas emissions. Large wildfires are common in these systems; these impact people through erosion and flooding, destruction of property, and impacts on air pollution and global air chemistry. Changes in fire regimes are a probable effect of global change in these systems. Impacts of global change on range and wildlife habitat also are important issues.

Other important ecosystems extend beyond the Pacific Coastal Region. Cooperative efforts with the Intermountain West region will take place to solve the complex problems of alpine ecosystems with their recreation and watershed values. The Pacific Coastal Region will continue to cooperate with the Southern Region and international researchers to investigate the response and management of tropical ecosystems.

UNIQUE RESEARCH CAPABILITIES OF THE PACIFIC COASTAL REGION

The Pacific Coastal Region boasts the largest, most diverse network of experimental forests and ranges, Experimental Watersheds, Research Natural Areas, Long-term Ecological Reserves in the United States, with sites ranging from the tropics to the alpine and boreal regions. Some of these sites have over 50 years of monitoring records on specific ecosystem characteristics.

This region has the longest track record of research on effects of atmospheric deposition on forest ecosystems, and the only documented evidence of adverse impacts of air pollution on forest health. There is a long record of ecosystem process research in this region, much of it dating from before the IBP program in the 1970s. The region also has qualified and experienced researchers in a wide range of fields, including physiology, hydrology, soil processes, air pollution, fisheries, wildlife, recreation, economics, fire ecology and management, smoke chemistry, meteorology, and biogeochemical cycling. Close and continuing partnerships also exist in the region, with scientists from many universities, agencies such as EPA, NASA, the National Park Service, numerous state and local agencies, and industry groups such as the Electric Power Research Institute.

SPECIFIC CONCERNS OF THE PACIFIC COASTAL REGION

<u>Terrestrial Vegetation, Life Histories and Distribution, and Community Composition</u>

- Determine effects of interacting stresses due to changing climate (temperature and hydrologic regimes), air chemistry (CO_2, trace gases), and pollution on vegetation dynamics, structure, composition, and distribution, on biological diversity, and on commodity production.

- Determine effects of changing climate and air chemistry on physiology, vigor, composition, and range of important species, and on optimum silvicultural management strategies. Develop and apply methods, such as remote sensing, for detecting stress in vegetation and predicting and monitoring vegetation change.

- Based on knowledge of potential effects of global change on ecosystems, monitor and

detect global change effects along a series of latitudinal and elevational transects in conjunction with long-term monitoring information from established experimental forests and watersheds and Long-Term Ecological Research sites (LTERs).

- Integrate this information into regional and national resource management models to predict impacts on resource production and human values, and develop appropriate resource management strategies to mitigate or adapt to effects.

Water Quality and Quantity, Erosion, and Sedimentation

- Determine effects of atmospheric deposition and changing climate on water chemistry.

- Determine effects of climate change on hydrologic processes, such as water yield, flood frequency and magnitude, timing, snow pack and permafrost influences, erosion, sediment transport, and stream channel stability.

Energy and Biogeochemical Cycles

- Determine effects of changing air chemistry (due to pollution, trace gas emissions, and combustion) and changing climate (both temperature and water regimes) on nutrient cycling, soil processes, organic matter accumulation and decomposition, and ecosystem structure and processes. Includes studies of effects of elevated UV-B radiation, and processes and fluxes of exchange of greenhouse gases (e.g., CO_2, CH_4, NO_x).

- Determine impacts of increased pollution and altered climate on human values, including recreation, in wildlands and at the wildland--urban interface.

- Develop methods for increasing resolution of global change models for interpreting results and making predictions on spatial and temporal scales relevant to regional effects and ecological processes.

- Determine the effects of changing vegetation and land-use patterns on the atmosphere; and interpret the influence of terrestrial ecosystems and land management on the atmosphere for global atmospheric models.

Aquatic Ecosystems and Wetlands

- Determine effects of climate-induced changes in hydrology and riparian zones on anadromous and resident fish habitats.

- Determine effects of climate changes on distribution, structure, and carbon, organic matter and trace gas cycling for wetlands and changes in distribution and structure of riparian areas.

Insects, Pathogens, and Microbes.

- Determine effects of global change on the population dynamics and distributions of forest insects and microorganisms. Evaluate use of insects and microorganisms as early indicators of environmental change.

- Determine the effects of global change on soil environments and rhizosphere processes.

- Determine the effects of changing environmental stress, including CO_2, UV-B radiation, drought, and temperature on the pest/pathogen/host interactions in forest ecosystems.

Fire Severity and Occurrence

- Determine effects of fire on chemical cycling. Includes effects of smoke emissions on climate and air quality, the role of fire in cycling of carbon, nutrients, and air pollutants, and effects of fire on greenhouse gas emissions from soils.

- Determine the impacts of climate change on fire frequency and severity and interpret the effect of changes in fire regime on ecosystem structure, function, and distribution.

- Develop and apply methods to measure and predict frequency, severity, emissions, and areal extent of fires. Integrate results into general circulation models.

- Model impacts of climate and pollution-induced changes for fire management and fire protection. Develop adaptive fire management strategies.

Wildlife and Domestic Species

- Determine effects of climate-induced changes in wildlife habitat on wildlife populations and distribution.

- Determine the potential impacts of global change on biodiversity and threatened and endangered species.

- Determine effects of global change on the quantity and quality of available forage for domestic livestock.

ASSESSMENT, MONITORING, RESPONSE STRATEGIES, AND POLICY ANALYSIS

PURPOSE AND SCOPE

A major objective of the USDA Forest Service Global Change Program is to conduct an assessment of current and future global forest resource conditions. The assessment will provide a scientific basis about trends in response to global change for the development of individual, public policy, and educational options. These options are intended to limit and mitigate gas emissions and adapt to a changing environment. Reliable information is essential for responsible resource stewardship and periodic resource assessments. The Forest Service has been granted legislative authority to perform these assessments. The Forest Service has developed substantial expertise, data bases, inventory and monitoring systems, models, and computer systems for conducting impact assessments. Components of the assessment will include: 1) description of basic trends, 2) description of current conditions, 3) projection of trends within the context of a changing environment, 4) outline of the potential response strategies to these projections, 5) definition of the uncertainties associated with all aspects of the assessment, and 6) simulation of the prospective changes in resource trends associated with various response strategies. However, global change is an issue of such unprecedented complexity that a considerable expansion and integration of existing assessment capabilities will be required.

ASSESSMENT AND PREDICTION OF FUTURE RESOURCES

Perceptions of change are most sensitive to seasonal to decadal regional weather trends, such as the droughts of the 1930's, 1950's, 1970's or the hot, dry years in the 1980's, and local to regional environmental changes, such as the impacts of acid rain or urban smog on vegetation. Increased understanding of the earth system has prompted a need to consider long-term changes, such as those associated with global change. There is great uncertainty in the projections of impacts from global change on local ecosystem responses. However, these factors will play a major role in landscape changes; for example, changes in precipitation and temperature will restrict the persistence of some ecological systems and the geographic distribution of agricultural crops. Changes in disturbances, such as fire, insects, and disease, will impose new and different stresses on natural and managed ecosystems. There is a need to assess impacts of global change on our renewable resources of soil, and water from forest, range, agricultural, and other associated ecosystems. Reliable estimates of the magnitude and rate of global change are needed at many decision levels within society: individuals, such as foresters, ranchers and farmers; industry, including processing, storage, and transportation; and government officials such as resource managers and regulators.

The assessment process represents the synthesis and integration of the results of research and resource monitoring in a product that seeks to address specific policy questions. Ecological, silvicultural, agricultural, and economic models will provide the tools for accomplishing this synthesis and integration.

The first step in the assessment will use models developed in "Ecological Systems Dynamics" to assess probable change. Such forecasts will be developed in cooperation with other government agencies and universities. Linkages between changes in atmospheric composition and climate changes will be established. This will involve forecasting altered temperature, rainfall, and storm patterns on a regional basis through the use of information derived from general circulation models. Methods and models to forecast long-term changes in regional and global temperature, rainfall, and storm patterns may be developed within the Forest Service and through cooperation with other government agencies, universities or private industry.

The assessment of human impacts on the environment will provide a basis for policy and educational responses that will limit adverse activities. The Forest Service and other federal agencies with educational responsibility and authority will cooperate to develop strategies that promote voluntary modification of behaviors. Policy options to regulate, or provide incentives for voluntary changes, and future research directions to limit human impacts also will rely on information from the assessment.

The second phase of the assessment will establish linkages between climatic changes and likely changes in the terrestrial and aquatic systems, and establish the feedbacks from these biological and physical environments into climate. The implications of these climate change impacts on agricultural and forestry production activities will be assessed, and impacts of agricultural and forestry activities on climate and the physical environment will be evaluated.

The biophysical assessment will provide an understanding of how climate changes affect the biosphere. This knowledge will be used to develop educational and policy responses intended to mitigate emissions or accommodate change. The assessment also will form the basis for future research about land-use alternatives and ecosystem management to help offset current and future emissions.

The third major phase of the assessment will determine how climate and environmental changes impact human populations and activities, and, importantly, determine how altered human activities influence climate change. Economic market analyses are one facet of human activities that will be examined. These analyses will include, for example, analysis of changes in all agricultural and forestry sectors due to global change. The analysis of human aspects will, however, go beyond market impacts to include the full spectrum of human interactions with the environment.

The fourth and final step of the assessment will identify various policy options for government officials and examine these options as alternatives for risk management. This step will bring the assessment process full-circle. The policy options will be examined for their ability to alter human activities. Altered human activities, in turn, will be studied as a means of conserving resources or limiting global change.

The large degree of uncertainty of changes precludes the sole reliance upon deterministic analyses. Thus, the threat of changes in agricultural and natural resources due to changes in the

atmosphere and their subsequent impact on human beings will be analyzed within a risk analysis framework dealing with probabilistic rather than deterministic results.

The changes examined in the assessment are likely to occur gradually over long time periods. The assessment will adopt this long-term perspective. Also, the scale of environmental change is such that partial equilibrium analyses will not be adequate. For example, it will not be realistic to examine only wheat production and markets within the United States without also examining global change-induced wheat production in the rest of the world.

The uncertainty of the extent and severity of global change and associated impacts requires flexible policies. Assessment of current knowledge and uncertainties ideally occurs regularly to allow continual policy updates as the facts/pictures change or unfold. The constant updates will provide policy makers with opportunities for course corrections. An assessment represents a culmination of global change research and monitoring as described in previous sections of this report. Individual programs are unified to create a picture of present and possible future global conditions. For this reason, it is important that the assessment activities begin early, essentially at the same time as the other scientific investigations. Throughout the course of the global change research program, administrators will provide direction to assure the integration of research findings into a coherent final assessment to best serve policy makers.

RESOURCE MONITORING

The Forest Service conducts a number of monitoring, inventory, and survey efforts that provide information needed by resource managers and policy makers on the status of fiber production and the ecological systems which support this production. Monitoring is the long-term, periodic measurement of selected physical and biological parameters for establishing baselines and detecting and quantifying changes over time. It forms the foundation on which two of the components of the assessment are based: 1) description of basic trends, and 2) description of current conditions. These data also are used in research activities, especially in the area of model development and verification. Monitoring also serves the purpose of verifying response to mitigation efforts.

Forest Health Monitoring

The Forest Service, in cooperation with state forestry organizations, has initiated a three tiered National Forest Health Monitoring Program. This Program is designed to integrate with and complement our overall Global Change Research Program. The three tiers in our Forest Health Monitoring plan are:

1. Detection Monitoring
2. Evaluation Monitoring
3. Research Monitoring

Contributing Forest Service Monitoring Programs

The Forest Service currently has three major monitoring programs directed at forests and related ecosystems. These include Forest Inventory and Analysis (FIA), inventory activities associated with the management of federal, state, and private forest lands, and the Forest Pest Management surveys of State and Private Forestry. FIA is the only public or private periodic forest resource inventory and evaluation. For most regions of the United States, FIA has developed data bases of forest resources that span 30 years,

with complete inventories conducted approximately every 10 years.

The Forest Service also conducts long-term, intensive monitoring of selected forest ecosystems such as research at the Coweeta Hydrologic Lab or the H.J. Andrews Experimental Forest. These monitoring activities will provide critical input to the global change assessment. Much of this current intensive monitoring takes place inside ecosystems rather than on the margins where change is most likely to be first detected. New Research Natural Areas will need to be established along and across ecotones to remedy this shortcoming.

Global Change Monitoring

Existing Forest Service monitoring programs provide a strong foundation on which to design and implement monitoring programs for assessment of the impacts of global change. In addition to providing accurate baseline and trend data on a wide array of parameters that have direct relevance to impacts of global change, these programs, with integration and expansion, will provide efficient and effective monitoring of global change impacts. A high level of coordination within the Forest Service will be required to achieve the needed integration. Maximum use of monitoring data will be achieved through coordination with other federal agencies, especially those focusing on monitoring and research of the physical and chemical climate. Within the Forest Service, the following tasks will be initiated in order to develop the level of resource monitoring required to detect and evaluate the effect of global change on the production of fiber, as well as forest health and sustainability, in the United States:

- Develop lists of specific parameters currently inventoried, surveyed, and monitored by Forest Service and other agencies, including the duration and frequency of collection.
- Evaluate the applicability of these data to monitoring the potential impacts related to global change.
- Identify additional parameters needed for the assessment of global change impacts on natural resources and crop production.
- Compile the spatial distribution of current monitoring activities and new additional parameters.
- Develop methods to use remote sensing for resource monitoring and establish an Earth Cover Identification System as a data collection system for national resource inventories.
- Develop and apply a geographic information system to provide the ability to analyze numerous resource data sets simultaneously across large geographic scales with overlays.
- Coordinate protocols for data collection and analysis and implement procedures to assure that the quality of these data are sufficient for their intended use.
- Develop a data reporting mechanism that provides direct access to monitoring data by Forest Service staff responsible for producing the assessment of global change impacts.
- Evaluate these monitoring activities to ensure provision of the appropriate data needed for the assessment.

A key element to the utilization of existing monitoring programs for assessment of global change impacts is the development of an efficient data management system. A centralized data

management program will be developed that focuses on global change and which will provide the mechanism for ensuring that relevant high quality data are readily accessible to scientists and policy makers.

CLIMATE SCENARIOS

The Forest Service Global Change Assessment will develop, in coordination with other researchers involved in climate and earth systems research, scenarios designed to span the range of potential changes in temperature, rainfall, and storm patterns globally and regionally. Intercomparison of existing GCMs' output has shown some consistency in the prediction of an increase in the equilibrium global temperature. The Forest Service, in cooperation with climate and earth systems researchers, will conduct an inter-model comparison of several climate forecasts to test the robustness of future climate projections. In a policy setting, the likelihood of a change in climate offers a way to assess the potential impact on forest, range, and agricultural resources.

The Global Assessment shall develop probabilities of occurrence associated with the spectrum of possible climate change scenarios. These probabilities of occurrence will provide information to compare the severity of impact on future resource production on forests, rangelands, and croplands. These probabilities of occurrence will be a function of the current understanding of global and regional mechanisms of climate. Each climate change scenario is influenced by the future concentrations of greenhouse gases, which are functions of human activities such as the burning of fossil fuels, deforestation, the burning of forests and by-products from agriculture. Projections of the future concentrations of these greenhouse gases will be developed based on forecasts of energy consumptions, energy efficiency, land use, and population growth.

ECOLOGICAL CONSEQUENCES OF CLIMATE SCENARIOS

Links to Climate Models

The Forest Service Global Assessment will be concerned with the linkages between climatic changes and likely changes in the natural and managed ecosystems, and the feedbacks from these biological and physical environments to climate. Direct, interactive coupling of the biosphere to the atmosphere in global models so that there is a direct exchange of mass and energy will need to be improved dramatically. Current approaches only attempt to describe heat and water vapor exchange and make little reference to the structure and composition of the ecosystem, to the abundance of individual species, or to any mediating effects of the biosphere on the atmosphere. Heterogeneity of land and water distribution on the surface of the earth contribute to the difficulty in interpreting mean values for climate over a varied region. Forest Service researchers, in cooperation with climate and earth systems researchers, will develop approaches to better quantify the biophysical components of these models and the role that the natural and managed ecosystems have in global change.

The Global Change Assessment will develop scenarios of future climate, including parameters such as precipitation and temperature. Without models that directly link atmospheric processes to ecological processes, climate projections from GCMs may be used to construct scenarios as a context in which to examine the behavior of ecological processes. These scenarios must reconcile climatic differences across different

geographic scales; GCMs operate on a large geographic scale, and policy options are needed for a more specific geographic region.

Ecological Models

Forest Service researchers are involved in the development of knowledge regarding basic relationships in plant development, community dynamics, ecosystem processes, as well as development of an understanding of the pattern induced by natural disturbances on the landscape. The Forest Service Global Assessment will be concerned with these basic processes and their changes under altered climates, as well as understanding how managed disturbances will amplify or diminish the natural disturbances, such as fire or insects, and how this interaction affects plant, community, and ecosystem dynamics.

Ecosystem models will focus on the biogeochemical processes of fixation, allocation and decomposition of carbon, and the cycles of nitrogen, phosphorus, sulfur, and other elements. Changes in rates of nutrient cycling may occur more rapidly than changes in species composition (days to years versus years to centuries), and thus change the environment for species interactions. Incorporation of nutrient cycling in gap-phase models has significance in determining the likely changes in species abundance and ecosystem processes on forest and rangelands.

The Global Change Assessment will translate the mechanistic understanding of the environmental impacts into an assessment of the implications on agricultural, forestry, and range resource production activities. In addition, the Global Change Assessment will evaluate the impact of agricultural, forestry, and range activities on climate and the physical environment.

Links to Policy Models

The management activities of forest, range, and agricultural land are motivated by the goals and objectives of human populations. There is a need to determine how future climate changes will impact human populations and activities through agriculture and forestry and how altered human activities through agriculture and resources management will affect global change. Economic and social changes relative to the supply and demand of renewable resources and agricultural resources will affect the appropriateness of conservation programs and the management of forest, range, and associated lands.

The Global Change Assessment will analyze the implications of renewable resource management and alternative soil and water conservation practices for the biophysical environment so that the appropriateness of future roles and programs of the Forest Service can be evaluated. This assessment will integrate agricultural and ecological sciences, focusing on the development of basic knowledge for use by policy makers concerned with analyzing policy options. The analysts associated with the Global Change Assessment will work with the policy makers to determine, in a quantitative manner, the impacts of global change that are currently understood and to project qualitatively how these effects will impact factors that cannot be directly linked to projection models.

LINKAGES BETWEEN ECOLOGICAL AND SUPPLY/DEMAND MODELS

As previously noted, the Resource Planning Act (RPA) Assessment has developed models and methods for analyzing the economic supply and demand situation for various agricultural, range,

and forest resources. The RPA Assessment focuses upon outputs such as timber, rangeland, water, freshwater fishing, outdoor recreation, and hunting. The Forest Service Global Change Assessment also will be concerned with analyzing these same supply and demand situations; thus, many of the models developed for use in the RPA processes will be appropriate starting points for these analyses. However, linkages to the models of ecological change must be established in order to ascertain the effects of global change.

Demand factors which are considered in the RPA analyses include the size and location of populations, gross national product, personal disposable income, institutional and technological change, energy costs, and capital availability. Global changes could have a profound effect upon such factors as the size and distribution of population, energy costs, and so forth, thereby altering the demand for forest and agricultural outputs. Additionally, there will be impacts on food and fiber storage, processing, transportation, and marketing sectors.

For the Global Change Assessment, linkages with the ecological models will be established so that the magnitude of changes in these demand-influencing factors can be determined. The ecological changes also will be linked to changes in supply-influencing factors. This will require the development of an understanding of the manner in which global change will alter land area, soil quality, species composition, vegetation growth rates, land ownership patterns, and pathogen/disease interrelationships. These relationships between ecological factors and production functions will be established through scientific experiments, field studies, theoretical models, and expert opinion. Past experience has shown that the most satisfactory results are obtained when supply/demand modeling evolves along with ecological modeling.

EXAMINATION OF MANAGEMENT RESPONSES

Changes in the environment represent potential new opportunities for managing silvicultural production systems. The future resource situation will be a function of human activities as well as environmental change. Forest Service policies are directed to develop and maintain sustainable forestry, and recognize that global change is a stress on forests. Global change is not the end point of policy development.

Alternative levels of resource protection will be realized under different policy options. Three broad options are: 1) conserving existing natural resources and agricultural potential in place, 2) mitigating effects of climate changes, or 3) adapting resource and agricultural production to the changing environment. A combination of any or all of these options also is possible, and different instruments will be used to implement them. The role of the Global Change Assessment is to project the implications of different policy options on the future resource situation. These and many other alternatives will be developed and evaluated in cooperation with the development and application of global change prediction models. It is important that management options also be evaluated in light of information gathered during the assessment and monitoring phases, and that the predictive models utilize the most current data.

Linkages between the impact of a number of policy instruments, resources, and agricultural productions have been established for the Forest Service Assessments and Appraisals. The Global Change Assessment will build on currently existing linkages and extend the analyses to include other policy instruments considered important in addressing global change. Mitigating the effects

of climate change will involve the global community. In areas where ecosystem productivity will be significantly altered, the tradeoffs between conserving existing resources and adapting the socio-economic system to new resources on forest, range, agricultural, and associated lands must be evaluated.

While conservation of some elements of existing ecosystems may be possible through such policy instruments as projects designed to support irrigation or fertilization, significantly different ecosystems will ultimately evolve in response to the changing climate. Instruments for an adaptive policy option may involve developing technologies to utilize the resources of the future ecosystems; importing new industries or businesses that are compatible with the resources of the future forest, range or agricultural systems; or relocating existing activities in anticipation of changing climate. An example of adaptation is no-till farming, which may reduce oxidation of soil organic matter. However, additional strategies will be developed.

Determination of future resource strategies will involve an examination of questions such as how much and which forest, range, and agricultural land should be managed for resource production. Also, alternative management strategies could have significant effects on future global changes, and these impacts also must be considered. The Forest Service is faced with situations of great complexity and with the challenge of developing appropriate data bases and models to provide a reliable basis for making decisions about management of different forest, range, and agricultural ecosystems, under conditions that involve a wide range of external variables. Extensive monitoring and assessment must be a continual part of meeting this challenge.

Data Management

The Global Change Assessment will require aggregation of large amounts of data collected by various organizations and in various regions of the United States. Data aggregation, as experience in the RPA Assessment has shown, is an integral part of the process and must be managed carefully to ensure that the needed data is available in a timely and consistent manner.

POLICY ANALYSIS

As mentioned above, Forest Service policies are directed to develop and maintain sustainable forests. The Forest Service is required to manage the National Forests of the United States and provide technical support to other forest managers and owners. Formulation and implementation of sustainable forest policy for forest management is based on the Forest Service leadership in forestry research and on the ability to apply science and technology in forest management. The Forest Service, as stewards of the National Forests, will lead the nation in establishing policy to manage the nation's forest resources in response to global change.

Currently the Forest Service is responding to global change concerns by reacting to EPA proposals, planning to plant more trees, and conducting additional research on global change impacts. Forest Service research will move beyond these initial steps and take a more active role in U.S., USDA, and Forest Service policy formation and implementation on issues related to global change.

We recommend a dynamic policy formation and analysis process in order to include global change concerns in policy formulations and implementation. The USDA should review existing Forest Service policy to identify areas where new or revised policy is needed and then provide the policy staff work for Chief and Staff review. In this process it is imperative that the administration's and other agencies' policies be reviewed for consistency and coordination.

Three alternatives for policy review were considered:

1. Charge the Policy Analysis Staff with responsibility for reviewing existing and proposed policy and recommending new policy involving global change for consideration by the Chief. This approach recognizes the process for policy review within Forest Service. However, the background and expertise of the Policy Analysis Staff may not be consistent with the types of information that must be applied to a review of Forest Service policy.

2. Establish a committee of experts (COE), chaired by the Forest Fire and Atmospheric Sciences (FFASR) Staff Director, with responsibility for review of existing as well as proposed Forest Service policy. This approach would use individuals knowledgeable on global change issues. However, this will tend to pull scientists away from their research responsibilities.

3. Form an amalgamation of 1 or 2 above. This approach provides a formal process for positive feedback from Chief and Staff and uses the best information for review. However, this also will tend to pull global change scientists away from research.

We recommend that a specially organized COE, recommended by FFASR and selected by the Chief, be established. The COE should have positive mechanisms to provide recommendations to the Chief and Staff.

Criteria that might be considered in the evaluation of specific policy proposals include the following:

1. Does the policy represent sound judgement independent of the impact of global warming? Sound policy is defined as being consistent with development and maintenance of sustainable forests. Does it make sense?

2. What level of risk is associated with the policy proposed? Is it based on sound science or preliminary results? If it is based on sound science, what is the likelihood that the projected results will actually occur?

3. Do benefits exceed costs for the proposed policy? For example, tons of carbon sequestered per unit cost and impacts on other resources are suggested criteria.

4. Is the policy politically feasible? Will it win public acceptance?

A successful policy support would entail establishing a feedback mechanism between research and policy. This needs to be a continuous process so that new research results will be a guide as to the viability of policy. On the other hand, new policy initiatives arising out of needed dynamic linkages both within and outside the Agency would require new initiatives to be incorporated in the research agenda. Research needs will be identified by the Committee of Experts. These research needs will be transmitted from Forest Fire and Atmospheric Science Research (FFASR) Staff Director to stations,

projects, and scientists through the Forest Service research organization. Funding/budgeting for these needs will be developed via normal budget processes in negotiation with the Staff Director of FFASR and Station Directors.

APPENDIX A: WORKSHOP PARTICIPANTS

<u>Intermountain Forest and Range Experiment Station</u>

Dr. Richard Krebill
Assistant Station Director
324 25th Street
Ogden, UT 84401
801-625-5410

Dr. James L. Clayton
Forestry Sciences Laboratory
316 E. Myrtle Street
Boise, ID 83702
208-334-1457

<u>Intermountain Fire Sciences Laboratory</u>

Dr. Darold Ward
P.O. Box 8089
Missoula, MT 59807
406-329-4866

<u>Rocky Mountain Forest and Range Experiment Station</u>

Dr. Hank Montrey
Station Director
240 W. Prospect Street
Fort Collins, CO 80256-2098

Dr. Doug G. Fox
240 W. Prospect Street
Fort Collins, Co 80256-2098
303-498-1231

Dr. Ray Czaplewski
240 W. Prospect Street
Fort Collins, CO 80256-2098
303-498-1231

Dr. Andrew Gillespie
Methods Application Group
3825 East Mulberry
Ft. Collins, CO 80524
303-224-1785

Dr. Linda Joyce
ECO Systems Center MBL
Woods Hole, MA 02543

<u>North Central Forest Experiment Station</u>

Dr. David C. Lothner
Assistant Station Director
1992 Folwell Avenue
St. Paul MN 55108
612-649-5249

Dr. Lewis F. Ohmann
Forestry Science Laboratory
1831 Highway 169 E.
Grand Rapids, MN 55744
218-326-8571

Dr. Judson G. Isebrands
Forestry Sciences Laboratory
Box 898
Rhinelander, WI 54501
715-362-7474

Northeastern Area State and Private Forestry

Mr. Leroy Johnson
State and Private Forestry
1992 Folwell Avenue
St. Paul, MN 55108
612-649-5242

Northeastern Forest Experiment Station

Dr. Christopher Eagar
Spruce-Fir Program Manager
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
Radnor, PA 19087
215-975-4034

Dr. Gerry Hertel
Forest Response Program Manager
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
Radnor, PA 19087
215-975-4030

Dr. Sheila Andrus
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
Radnor, PA 19087
215-975-4222

Dr. Beth Adams
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
Radnor, PA 19087
215-975-4222

Dr. Keith F. Jensen
Forestry Sciences Laboratory
359 Main Road
Deleware, OH 430
614-362-8505

Pacific Northwest Forest and Range Experiment Station

Dr. Arthur L. Schipper
Assistant Station Director
P.O. Box 3890
Portland, OR 97208
503-326-5642

Dr. David V. Sandberg
Forestry Sciences Laboratory
4043 Roosevelt Way N.E.
Seattle, WA 98105
306-442-7815

Dr. Charles W. Slaughter
Institute for Northern Forestry
308 Tanana Drive
Fairbanks, Alaska 99775-5500
907-474-7443

Pacific Southwest Forest and Range Experiment Station

Dr. Enoch F. Bell
Assistant Station Director
1960 Addison Street
Berkeley, CA 94704
415-486-3436

Dr. Susan G. Conard
Forest Fire Laboratory
4955 Canyon Crest Drive
Riverside, CA 92507
714-276-6560

Dr. Mark Poth
Forest Fire Laboratory
4955 Canyon Crest Drive
Riverside, CA 92507
714-276-6571

Dr. Robert R. Ziemer
Redwood Sciences Laboratory
1700 Bayview Drive
Arcata, CA 95521
707-822-3691

Southeastern Forest Experiment Station

Mr. Joseph E. Barnard
Vegetation Survey Program Manager
Forestry Sciences Laboratory
Box 12254
Research Triangle Park, NC 27709
919-549-4020

Ms. Susan Medlarz
Acting Southern Commerical Program Manager
1509 Varsity Drive
Raleigh, NC 27606
919-737-3520

Dr. J. Edward de Steiguer
Forestry Sciences Laboratory
Box 12254
Research Triangle Park, NC 27709
919-549-4010

Southern Forest Experiment Station

Dr. Stanley J. Barras
Assistant Station Director
T-10210
U.S. Postal Building
701 Loyola Avenue
New Orleans, LA 70113
504-589-6800

Dr. James P. Barnett
Alexandria Forestry Center
2500 Shreveport Highway
Pineville, LA 71360
318-473-7216

Dr. Paul Van Deusen
T-10210
U.S. Postal Building
701 Loyola Avenue
New Orleans, LA 70113
504-589-4544

Forest Products Laboratory

Dr. John I. Zerbe
One Gifford Pinchot Drive
Madison, WI 53705-2398
608-264-5600

USDA Forest Service Washington Office - Research

Dr. Thomas E. Hamilton
Associate Deputy Chief
P.O. Box 96090 - 3007 SB
Washington, D.C. 20090-6090
202-447-4507

Dr. Paul H. Dunn
Forest Environment Research
P.O. Box 96090
Washington, D.C. 20090-6090
202-453-9561

Dr. William T. Sommers
Director, Forest Fire and
Atmospheric Sciences Research
P.O. Box 96090
Washington, D.C. 20090-6090
202-453-9561

Dr. Michael A. Fosberg
Forest Fire and Atmospheric
Sciences Research
P.O. Box 96090
Washington, D.C. 20090-6090
202-453-9561

Dr. Robert Bridges
Forest Insects and Diseases Research
P.O. Box 96090 - 609 RPE
Washington, D.C. 20090-6090
703-235-8065

Dr. Richard A. Birdsey
Forest Inventory, Economics, and
Recreation Research
P.O. Box 96090 - 4210 SB
Washington, D.C. 20090-6090
202-382-9341

Dr. Les Whitmore
Timber Management Research
P.O. Box 96090 - 1205 RPE
Washington, D.C. 20090-6090
703-235-8200

Dr. Dick Cline
Forest Environment Research
P.O. Box 96090 - 610 RPE
Washington, D.C. 20090-6090

<u>Forest Service Region 8</u>

Mr. Paul Berran
Center for Forest Environmental Studies
Rt. 1, Box 182A
Dry Branch, GA 31020
912-744-0210

<u>National Forest System</u>

Mr. James Byrne
Watershed and Air Management
P.O. Box 96090 - 1210 RPE
Washington, D.C. 20090-6090
703-235-8180

<u>Non-Forest Service</u>

Dr. David Correll
Smithsonian Environmental Research Center
P.O. Box 28
Edgewater, MD 21037
261-4190/301-798-4424

Dr. Diane Wickland
NASA
Room 225
600 Independence Avenue SW
Washington, D.C. 20546
202-453-1720

Dr. Anthony Janetos
U.S. Environmental Protection Agency
RD-682, Room 613A
401 M Street, SW
Washington, D.C. 20460
202-382-5791

Dr. Bill Gregg
U.S. Department of Interior
National Park Service
P.O. Box 37127
Washington, DC 20013
202-343-8122

Dr. John Huckabee
Electric Power Research Institute
P.O. Box 10412
Palo Alto, CA 94303
415-855-2589

Dr. Ata Qureshi
Climate Institute
316 Pennsylvania Avenue, SE
Suite 403
Washington, D.C. 20003
202-547-0104

Meeting Facilitator

Dr. Jay Jacobson
Boyce Thompson Institute for Plant Research
Cornell University
Tower Road
Ithaca, NY 14853-1801
607-254-1242

Science and Policy Associates, Inc.

Susan Morschauser
Leslie Gallo
Whitney Carroll
Melissa Eichner

The West Tower
Suite 400
1333 H Street, NW
Washington, DC 20005
202-789-1201

APPENDIX B: BREAKOUT GROUP PARTICIPANTS

NORTHERN REGION

Chris Eagar - Chairman
Beth Adams
Sheila Andrus
Rich Birdsey
Dave Correll
Mike Hall
Gerry Hertel
Jud Isebrands
Tony Janetos
Keith Jensen
Leroy Johnson
David Lothner
Lewis Ohmann

SOUTHERN REGION

Susan Medlarz - Chairman
Joe Barnard
James Barnett
Stan Barras
Robert Bridges
Bill Gregg
Ata Qureshi
Ed de Steigure
Paul Van Deusen
Les Whitmore
John Zerbe

INTERIOR WEST REGION

Doug Fox - Chairman
James Byrne
Tom Clayton
Dick Cline
Ray Czaplewski
Mike Fosberg
Andrew Gillespie
Linda Joyce
Dick Krebill

PACIFIC COASTAL REGION

Sue Conard - Chairman
Enoch Bell
Paul Dunn
John Huckabee
Mark Poth
Dave Sandberg
Art Schipper
Charles Slaughter
Robert Ziemer

ASSESSMENT

Rich Birdsey - Chairman
Beth Adams
Linda Joyce
Mark Poth
Ed de Steiguer
Les Whitmore

RESPONSE STRATEGIES

Gerry Hertel - Chairman
Sheila Andrus
Paul Dunn
Jud Isebrands
Leroy Johnson
John Zerbe

POLICY SUPPORT NEEDS

Mike Fosberg - Chairman
Stan Barras
Enoch Bell
John Huckabee
Tony Janetos
Dave Lothner
Ata Qureshi
Art Schipper

MONITORING

Joe Barnard - Chairman
Robert Bridges
Jim Byrne
Jim Clayton
Dick Cline
Dave Correll
Andrew Gillespie
Bill Gregg
Keith Jensen
Charles Slaughter
Paul van Deusen
Robert Ziemer

MODELING

Jud Isebrands - Chairman
Ray Czaplewski
Doug Fox
Tony Janetos
Linda Joyce
Others as Desired from Regional
Breakouts

REGIONAL INTEGRATION GROUP

James Barnett
Sue Conard
Chris Eager
Doug Fox
Jay Jacobson
Rich Krebill
Susan Medlarz
Lew Ohmann
Dave Sandberg
Bill Sommers

Forest Service Global Change Research Program

Washington Office - FFASR

Dr. William T. Sommers - Director
Dr. Elvia E. Niebla - National Program Coordinator
Dr. Michael A. Fosberg - Response Strategies & Policy
Dr. David L. Radloff - Forest Health Monitoring

USDA Forest Service
P.O. Box 96090
Washington, DC 20090-6090

(202) 453-9561

Pacific Coastal
Dr. David V. Sandberg
USDA Forest Service
4043 Roosevelt Way, NE
Seattle, WA 98105
(206) 442-7815

Southern
Ms. Susan Medlarz
1509 Varsity Drive
USDA Forest Service
Raleigh, NC 27606
(919) 737-3311

Interior West
Dr. Douglas G. Fox
USDA Forest Service
240 West Prospect
Fort Collins, CO 80526
(303) 498-1231

Forest Products
Mr. John I. Zerbe
USDA Forest Service
One Gifford Pinchot Drive
Madison, WI 53705
(608) 264-5753

Northern
Dr. Christopher Eagar
USDA Forest Service
5 Radnor Corporate Center
Suite 200
100 Mattsonford Road
Radnor, PA 19087
(215) 975-4034

Forest Health Monitoring
Mr. Joseph E. Barnard
USDA Forest Service
Box 12254
Research Triangle Park
NC 27709
(919) 549-4020

APPENDIX D: MONITORING ISSUES

FOREST HEALTH MONITORING

Factual information and correct interpretation of forest health, productivity, and diversity in the context of global change and other environmental issues is critical to public policy, land management and individual ownership decisions. The USDA Forest Service is developing a forest health monitoring program.

Currently, the Forest Service gathers data about the forest resource and its health in various ways. The two activities most germane to this discussion are the periodic Forest Inventory and Analysis (FIA) surveys and specific insect and disease surveys conducted or coordinated by the Forest Pest Management (FPM) division of the State and Private Forestry. These two activities supplement each other. The periodic forest resource inventory records tree mortality as well as many other attributes on a network of permanent ground plots, while the specific insect and disease surveys, based on aerial and/or ground samples, record short-term changes in pest activity.

Since 1984, the Forest Response Program has sponsored a number of monitoring-related research activities. The activities supplement the nationwide network of Experimental Forests, Ranges and Watersheds. Full implementation of comprehensive forest health monitoring is the next step. This will build on past research and experience gained from pilot tests, specialized forest health monitoring, operational forest inventories, and forest pest evaluation activities. The current Forest Inventory and Analysis and Forest Pest Management inventories of the USDA Forest Service will provide the base monitoring network. This broad-based network will be supplemented by several additional components including forest pest surveys and targeted monitoring of priority areas.

Forest health monitoring will be a multi-tiered, long-term process to (1) detect unexpected deviation from established baseline conditions or trends, (2) identify cause, and (3) define basic relationships sufficient to predict consequences. Each successive tier requires progressively more detailed and costly information. The three tiers, further defined as monitoring, evaluation monitoring, and research monitoring, are essential to a successful forest health monitoring system.

The scope of forest health monitoring will be such that it addresses forest health relative to effects of both naturally occurring factors such as fire, forest pests, forest succession, and drought, and unnatural biotic and abiotic, including anthropogenic factors such as introduced pests, air pollution, acid deposition, and climate variability. The term forest health describes forest ecosystem resilience and productivity relative to public values, needs, and expectations. A healthy forest can be described by different standards, each related to differing management objectives for particular forested areas. The first step toward evaluating forest health is describing forest condition. The three levels of monitoring described above will provide a thorough description of forest condition, as well as sufficient information on causality to enable evaluation of forest condition in terms of forest health.

Formal mechanisms which assure that early identification of change, assessment of the causes of change, the research on the basic mechanism, and follow through to transfer of the knowledge to forest managers will be established. Also, a data management system will be required. The design of this system is currently underway.

APPENDIX E: MODELING ISSUES

The false assumption that we live in a stable unchanging climate is being further challenged by the increase of carbon dioxide and other radiatively active gases. The build up of these gases could lead to changed global mean temperatures, changes in precipitation patterns, increases in atmospheric pollutants, and secondary impacts of those changes. These impacts include alterations in insect and disease outbreak or forest fire frequency and severity.

In order to prepare for the future, the Forest Service must have the capability to forecast that future. Forecasting the future requires that we have an accurate assessment of the current state of the environment and the capability to determine the rate of change of both the external forces of change and how the natural environment responds to that change.

Assessment of the current state of the environment is covered in the Research Plan and in Appendix D on monitoring. An accurate assessment of the rate of change, and the uncertainties associated with those changes, are called for in the chapter on Assessment, Monitoring, Response Strategies and Policy Analysis, and in specific strategies in the Research Plan. In this appendix, we will describe the specific strategies to integrate those activities through a basic philosophy on predicting the future. We cannot monitor the future, so we must use our understanding of the physical and biological processes to model or simulate future conditions.

Our current knowledge of global change is based on a large number of projections of population growth, energy consumption, and pollutant production per capita, and how those projections will define our future environment. There are a number of uncertainties in each of these projections. Equally, there are a number of uncertainties in the outcome of these uncertainties in what our future physical environment might be -- e.g., the general circulation models of the atmosphere give differing results for a doubled carbon dioxide concentration in the atmosphere. Our knowledge of the response of the biosphere to such externally imposed change introduces additional uncertainty. Current models of individual organism or community response do not include catastrophic disturbances such as fire or insect and disease outbreaks. Also, our quantitative knowledge base is limited to individual organisms or small communities, and does not include the landscape or ecosystem response to change.

Our strategic plan will include the mechanisms to move from our current assessment and knowledge base to an understanding and predictive capability for determining the responses of the biosphere to global change at the landscape and ecosystem level. Such predictive capability will include an explicit expression of the uncertainties in the physical environment and the biosphere responses. The Forest Service program also will include, through RPA, forest plans, and other resource management planning, an analysis of how these physical changes and biosphere responses influence the economy and social relations with forests.

In order to assure that the Forest Service can react responsibly to global change challenges, and

to use modeling as a means of predicting the future and evaluating policy options, the Forest Service will:

1) Hold a workshop of scientists, planners and managers on modeling global change in late 1990 or early 1991. The workshop objectives will include:

   - Develop a Forest Service philosophy on modeling;

   - Clarify links to databases;

   - Clarify how uncertainties will be incorporated into modeling;

   - Clarify how regional/ecosystem similarities and differences can be integrated when the forecast models differ in level of science and social detail and express uncertainty in differing ways to meet local and regional needs;

   - Identify strengths and weaknesses in the current research program;

   - Identify and prioritize a modeling/research program to overcome the weaknesses; and,

   - Provide guidance to stations and Washington Office staffs on modeling/predicting the future through timely publications of a workshop report.

2) Implement the workshop report recommendations through informing Washington Office staffs and stations, and through the normal budget process.